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OAIP

ONTARIO ASSESSMENT INSTRUMENT POOL

Teaching and Learning Chemistry in Ontario in the Senior Division

OAIP

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ASSESSMENT
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Teaching and Learning Chemistry in Ontario in the Senior Division

Teachers, students, content, methods, attitudes, and achievement

Leslie D. McLean

Report of a province-wide survey conducted in May 1983 as part of the field trial of the Chemistry OAIP.
The project was funded under contract by the Ministry of Education, Ontario.
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TEACHERS

EXPERIENCED, QUALIFIED, HARD-WORKING, INDEPENDENT

> . . . in practice, teachers are concerned with maintaining their credibility, exerting their influence, gaining access to scarce resources, coping with conflicts between outside expectations and the realities of the classroom, coping with a lack of skill to teach science as innovators imagine it should be taught, fulfilling the expectations of authorities, and resolving conflicts between students' interests and the demands of the subject.
>
> --John Olson and Thomas Russell, 1984

This daunting portrayal of the challenge teachers face is a useful introduction to a description of Grade 12 and 13 Chemistry teachers in Ontario in 1983. Who is it that takes up such a challenge? What preparation do they have? Over 500 teachers participated in the Field Trial and the accompanying survey.[1] Three-quarters of them completed a 10-page questionnaire about themselves, about the organization of the school and the way they teach Chemistry; 10 per cent of them wrote extended comments on the questionnaire, explaining their responses or adding to the information requested. A copy of the questionnaire, of which 376 were completed and are available for analysis, is included in Appendix A. This report is based on replies to that questionnaire, on responses from students to their own questionnaire, and on results from the assessment instruments that were the main focus of the Field Trial.

Half of Grade 12 and one-third of Grade 13 classes were organized on a semester system, and some full-year classes (16 and 13 per cent, respectively) were scheduled in double periods. These patterns are set out in detail in Table 1.

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[1] A detailed report of student performance on the assessment instruments has been published. Irwin Talesnick and Les McLean, Student Achievement in Grade 12 and Grade 13 Chemistry Classes: Report of the 1983 Field Trial of the Chemistry OAIP. Toronto: Ontario Ministry of Education, in press.

TABLE 1

Pattern of Organization of Chemistry Classes with Double Periods, Semesters in Grades 12 and 13

Grade 12

		Double Periods (%) Yes	No	No. of Classes
Semester?	Yes	17	83	75
	No	16	84	143

Grade 13

		Double Periods (%) Yes	No	No. of Classes
Semester?	Yes	9	91	32
	No	13	87	67

Experience

The low rate of recruitment of new teachers in recent years is reflected in the Field Trial sample. More than 80 per cent of teachers reported 11 or more years of teaching experience, and 97 per cent 6 or more years. A strong majority (70 per cent) have been teaching Chemistry since starting to teach.

The rapid expansion of the school system in the 60s is revealed in the age distribution of teachers. Nearly 50 per cent are under 40 years of age and 80 per cent are under 50. Thus, most will not be eligible to retire for at least 10 years. In the 10 years after 1995, however, about 80 per cent of teachers now teaching Chemistry will leave the system if all exercise their option. Should this rapid exodus occur, there will be numerous instances of teacher shortage. Students who entered Grade 1 in 1984 may find their science options reduced when they reach secondary school.

Qualifications

Since this was a survey of Grade 12 Advanced and Grade 13 classes, it came as no surprise that almost all teachers (91 per cent) had a specialist certificate. Of those replying (90.4 per cent), three-quarters reported that their certificates were in Chemistry or Chemistry plus other science, with 13 per cent in Biology. Six per cent reported a certificate in subjects other than mathematics or science.

One in five teachers had a graduate degree in science or in education, and 29 per cent had some industrial experience. Those who had industrial experience were more likely to have a graduate degree.

Teachers reported using a variety of methods to keep their knowledge up to date. Attending workshops and seminars in their field was the most popular method (76 per cent), followed by reading new material in their field (56 per cent). Half the teachers reported both. Fewer than one in five used extension courses or visited industrial settings.[2] Fifteen per cent checked the alternative, no systematic updating.

The question, "What local activities would be most useful to you for updating your chemistry?", was followed by eight options, from 1/2 day workshops on a topic to university courses, and including industrial visits and reading. The most frequent choice by far (48 per cent) was 1-day workshops on a topic, with half-day workshops, industrial visits, reading, and one-week seminars the choice of just over a quarter of the teachers. Night courses were seen as useful by fewer than one teacher in 10, but almost all chose a combination of the other options. Half the teachers would combine one-day workshops with industrial visits, reading, and one-week summer courses.

[2] An Advisory Committee member advised that there are few extension courses available.

When asked, "Are the professional development activities available to you adequate?", half of the teachers replied no. In 15 of the 48 boards of education represented in the sample, a large majority of these Chemistry teachers (70 to 80 per cent) responded no. Thus, it appears that teachers in about one-third of the boards gave most of the no responses. In the other two-thirds of the boards, 70 to 80 per cent of the teachers said the available professional development activities were adequate.

Teacher Workload

Few if any teach only Chemistry, but there must be some who do, because six teachers reported teaching five or six sections of Chemistry per year. The median number of sections of Chemistry per year was two, with 50 per cent of teachers reporting one, two, or three. Two-thirds of Grade 12 teachers and three-quarters of Grade 13 teachers also teach General Science, but, beyond that, a diversity of courses was reported, with no combination dominating. All combinations of teaching loads are described in Table 2.

TABLE 2

Percentages of Chemistry Teachers Who Taught Various Combinations of Courses in Grade 12 Grade 13

To read the table:

The first number in each column is the percentage of teachers in the Field Trial who taught that subject. Thus, under "Chem", the first number is 100 because all taught Chemistry. Only 21 per cent also taught "Math", as seen in row 4 (twice). In row 5, under "Chem", the figure 67 indicates that 67 per cent of Chemistry teachers also taught "General Science". Row 4 shows that 8 per cent taught both Physics and Math (in addition to Chemistry).

Grade 12

	1. Physics	2. Chem	3. Biology	4. Math	5. General Science	6. Other Science	7. Other
1. Physics	29						
2. Chem	29	100					
3. Biology	07	26	26				
4. Math	08	21	05	21			
5. Gen Sci	19	67	16	12	67		
6. Science	00	05	01	01	03	05	
7. Other	00	08	02	02	04	01	08

Grade 13

	1. Physics	2. Chem	3. Biology	4. Math	5. General Science	6. Other Science	7. Other
1. Physics	29						
2. Chem	29	100					
3. Biology	04	15	15				
4. Math	05	11	01	11			
5. Gen Sci	18	73	11	08	73		
6. Science	01	94	01	01	03	04	
7. Other	02	05	01	01	02	00	05

The question, "On the average, what is your total instructional time per class per week (in minutes)?", yielded responses quite consistent with Ministry policy. The median time reported in Grade 12 year-long classes was 190 minutes, which would be 4 hours over the 110-hour minimum, assuming 36 weeks of instruction. A quarter of the teachers reported spending over 200 minutes per class per week. Grade 13 teachers in year-long classes gave almost identical reports.

In Grade 12 half-year (semester) classes, the median was 357, which translates to 107 hours for 18 weeks. Since half of the teachers reported less than 357 minutes per class per week, there may be, on average, fewer hours of instruction in half-year classes. This is corroborated by other evidence, as will be seen in later sections. The Grade 13 half-year median was 364, which translates almost exactly to 110 hours for 18 weeks. Instructional time is not a precisely defined term, so some variation from the median would be expected, simply from different interpretations. The narrow range of reports is thus evidence for quite similar amounts of class time in schools across the province.

The Implemented Curriculum—Teachers' Choice of Topics

Teachers appear to use their time in very different ways. The questionnaire (Appendix A, pp. 72, 75, and 76) asked about time spent on topics and the emphasis given to different objectives in Chemistry classes. For every topic and every objective there was a large range of responses, with no strong pattern. Within the school's course of study, teachers are free to choose the content and emphasis they give to their courses in any given year, and they exercise that freedom. They are independent professionals and behave accordingly. We know from anecdotal reports that there is more likely to be consensus within departments, but the design of the survey did not permit us to explore this possibility.

Eleven topics from the Grade 12 Guideline were listed, and those teaching Grade 12 in 1982-83 were asked to "indicate the approximate number of hours your Chemistry classes spend on the following topics."[3]

The summaries presented in Figure 1 show how much difference teachers reported in time spent on three topics—one topic which, on average, was taught the greatest number of hours, and two the least. "The Mole, Atomic Weight, Molecular Weights" was assigned the greatest number of hours (median 10). "Oxygen and Hydrogen" and "Ions in Aqueous Solution" were not taught (at least not separately taught) by 25 per cent of teachers, and half of the teachers spent three hours or less on the topic. The graph of the range is given, because no single number could capture the range of values from no hours at all to over 20 hours for "The Mole, Atomic Weight, Molecular Weights".

Thinking that these single-topic summaries might hide some consistent patterns—different teachers all teaching the same set of topics, for example—correlations were calculated among the topics.[4] No clear pattern emerged, suggesting that many possible combinations of hours were used by teachers. Such a result suggests that we will not learn very much about teaching and learning if we only compare gross achievement results across classes, since the students in the classes were taught different combinations of Chemistry topics for different amounts of time.

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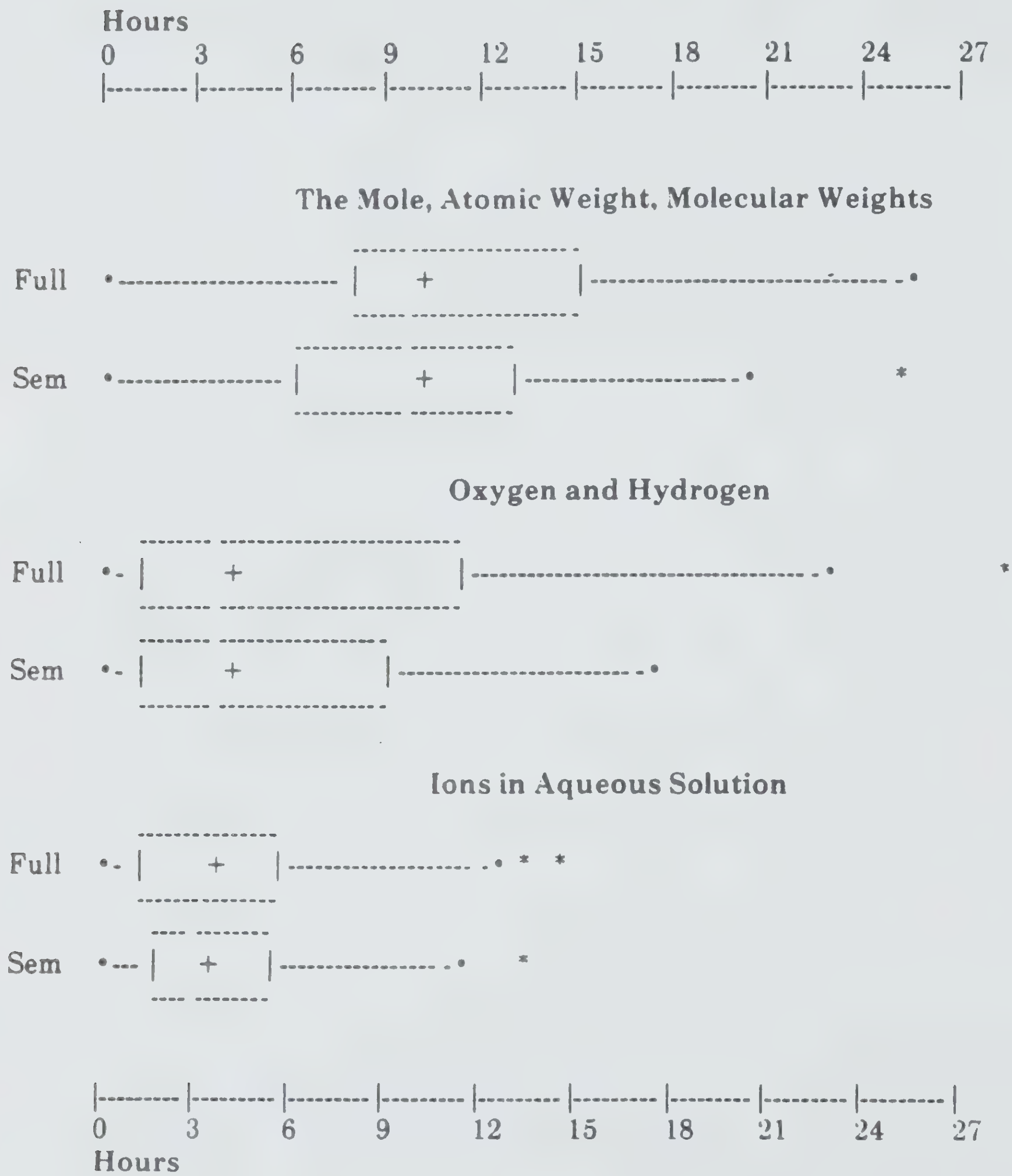
[3] Teachers were asked to enter zero if they did not cover the topic, and to use approximate hours to the nearest whole number. The number of hours is difficult to estimate for topics taught throughout the year, as part of other topics, so there may appear to be more variation among teachers than there actually is.

[4] Correlations are statistics that measure degree of association between two variables. If high hours on one topic are associated with high values on another, and vice versa, the correlation between the topics would take a value near +1. If teachers followed no consistent pattern, however, the correlation would be near zero. Over half were near zero, and all but a few were small. The full correlation matrix is presented in Table 7.

Figure 1: Distribution of number of hours per chemistry topic reported by Grade 12 teachers in full-year and half-year (semester) classes.*



*The cross (+) marks the median, the box encloses the middle 50 per cent of teachers and the dotted lines extend to the highest and lowest number of hours reported. Asterisks (*) are printed where extreme values were found--1.5 or more box-lengths from the end of the box--and capital letter O is printed where values were more than 2.0 box lengths from the end of the box.

Time Spent on Experiments and Other Activities

Section IX of the questionnaire asked the teachers, "Over the instructional year, what percentage of class time do students spend...", followed by nine activities and a residual category, with a line at the bottom and a total of 100 per cent listed (Appendix A, p. 77).[5] The first four categories referred to experiments: doing, discussing, writing up, and making graphs from. The median percentage report for doing experiments was 20 in Grade 12 and 18 in Grade 13. When the first four were combined, the median percentage (for all four) was 45 in Grade 12 and 39 in Grade 13. As one would expect, lots of time is spent on experiments in Chemistry classes. What was not expected was the large range in time spent on experiments. About 10 per cent of teachers spent less than 10 per cent of their time on all four experiment activities put together. More than a quarter of the teachers reported that they spent more than half their time on the four activities. The role of experiments is sufficiently central to the study of Chemistry teaching and learning that many different parts of the survey were focused on them, and a separate chapter is devoted to them in this report.

The other category on which teachers reported spending large percentages of their time was doing problems in class. The median percentage in Grade 12 was 20, and in Grade 13 it was 23; more time was spent doing problems in class in Grade 13 than in Grade 12 (the opposite from the pattern for experiments). Just as with experiments, though, the range of percentages went from 0 to 75 or 80. Full details are provided in Section 3.

Few, if any, patterns were in evidence, since correlations among the reports were low. Constraining the total to 100 per cent (or nearly so) meant that time spent on one category could not be time spent on another, so all of the correlations are negative. The largest correlation is -0.49, between the total of the four experiment

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[5] Only about half of the teachers took the time to enter percentages adding up to 100. All the results in the text are based on teachers whose total fell in the range 97 to 103 per cent.

categories and the residual category, other. The correlations are slightly higher (in absolute value) among Grade 12 class reports than among the Grade 13s. As we will see again and again, no one feature of teaching is strongly related to student achievement. Allocation of time to activities is no exception, although there were weak relationships overall between one or two of the time percentages and student achievement.[6]

In Grade 13, the percentage of time devoted to discussion of scientific issues and values was positively correlated with achievement, and doing problems in class was negatively correlated. In other words, students in the classes that spent more time on discussion and less in working on problems answered more of the achievement questions correctly. Together, these two variables predicted about 17 per cent of the variance in the aggregate Grade 13 achievement measure.[7] A very small correlation was observed in Grade 12 classrooms between achievement and time spent on activities other than those listed, but the influence, if any, is negligible.[8] This may not sound like very much, but in educational research it is rare to find two variables as strongly linked to an achievement variable. The exceptions are intelligence and social class.

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[6] The measure of student achievement used was the average over the topics most often taught, separately for Grades 12 and 13, and included a class only when there were 10 or more responses from that class to each topic. Topics included were numbers 1-9 and 12 (see Appendix A, p. 72), omitting Elements of Group 2 and Elements of Group 7, for Grade 12, and numbers 17-22, 24-27 and 30 for Grade 13. There were only a few items in the field trial for each of the dropped topics, with the result that only a few responses were obtained for most classes. The procedure also meant that small classes were also dropped, those with fewer than nine students, as it turned out. When the remaining achievement scores were linked with the time reports from the teachers, the sample was further reduced. These results are therefore based on only 120 classrooms, and thus may not be representative of the province.

[7] When the five time measures were tried in a regression analysis, only discussion and problem time were significantly related to Grade 13 achievement ($p<.01$). The squared multiple correlation was 0.17. A member of the Advisory Committee suggested that more discussion might indicate better teacher-student rapport and also a greater willingness on the students' part to try to answer achievement items not counting toward their mark.

[8] Squared multiple correlation 0.02.

Some Reasons Why Some Students Do Poorly in Chemistry

Section VII of the teachers' questionnaire asked, "To what extent do the factors below contribute to poor achievement in chemistry?" Seventeen possible reasons (factors) were listed, from Too many students per class to Too many Chemistry topics to cover adequately in school year. A five-point scale was provided for responses:

1	2	3	4	5
Not at all	To a small extent	To some extent	To a significant extent	To a great extent

On average, teachers (both Grade 12 and Grade 13) were agreed on 10 factors that did not contribute to poor achievement and seven factors that did. Teachers were emphatic, for example, that at this level, at least, student misbehaviour was not a factor that contributed to poor achievement in Chemistry. The strongest factor by far was student failure to do homework. In general, the reasons for poor achievement are laid squarely at the students' door. Responses are summarized in Table 3.

Summary

Ontario Chemistry teachers are an impressive group. It would seem from the statistics that they are in the early years of a period of prime teaching activity that should continue for at least another 10 years. They are highly qualified and well experienced, and four out of five of them are between 30 and 50 years of age. Most teach several different subjects at several levels of the school system. A large majority assign a significant amount of homework, and almost all give examinations either at the end of the course or during the course. As we will see later, students held positive views of science, and Chemistry in particular.

TABLE 3

Contributions to Poor Achievement in Chemistry, According to Chemistry Teachers*

This table tells us:

Teachers believe that course design, teaching and other contextual factors do not contribute to poor achievement. The problem is that students do not work hard enough.

These factors are generally believed to contribute to poor achievement

Student failure to do homework (3.62)

Student failure to accept responsibility (3.29)
Student absenteeism (3.16)
Student lack of ability (3.04)
Generally low student motivation (2.99)
Insufficient time to deal with individual student difficulties (2.97)

Too many students per class (2.79)

Students not properly prepared (2.67)
Too many chemistry topics to cover adequately in school year (2.64)

Second group—generally not contributing to poor achievement

Student misbehavior (1.84)

Too many students whose first language is not English (2.05)

Inappropriate teaching materials (2.18)
Chemistry content is too difficult (2.18)
Insufficient teaching materials (2.25)
Inadequate demonstration materials (2.26)
Students did not find the course was what they had expected (2.27)

Out-of-date equipment or facilities (2.42)

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* The numbers in parentheses are averages on the five-point scale on which 1 was Not at all.

The two groups of reasons emerged from analysis of the correlations among the teachers' responses by the method of factor analysis. The reasons have been reordered by average teacher response rather than by correlations with the two factors.

As would be expected of qualified professionals, teachers exercised independent control over what they taught and how they taught it, within the broad guidelines provided by the Ministry of Education. The content of topics is not precisely defined. As a result, there appear to be as many Chemistry courses as there are Chemistry teachers. Setting a common examination that would be fair to all students would require identification of the content common to the courses, by whatever name it might be known.

Some find such diversity unacceptable, believing that high quality is only attained when a common core of topics is taught well by all, enforced by a common examination. This position is not in accord, however, with the national study of science education recently completed under the aegis of the Science Council of Canada.[9] The recommendations for science education coming out of that study stress the need for a more authentic view of science, an emphasis on the science-technology-society connection, setting science in a Canadian context, and introducing more technology education.[10] These goals are most likely to be achieved by a cadre of experienced, qualified professionals who select the topics and the emphasis that best suit their own resources and those of the students. The Science Council researchers were highly critical of science teaching in Canada overall, but from the present study it would seem that better results should be expected from the senior division in Ontario. We will be examining this possibility in more detail in the chapters that follow.

The characteristics that make the teaching corps strong at the moment are also cause for concern, because so many of those now teaching will retire over a short period beginning just over 10 years from now. There are no places for new teachers at the moment, nor will there be in the next few years. On the contrary, the decrease in

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[9] The main summary volume, one of six, is Report 36. Science for Every Student--Educating Canadians for Tomorrow's World. Available in Canada through authorized bookstore agents and other bookstores or by mail from the Canadian Government Publishing Centre, Supply and Services Canada, Hull, Quebec, K1A 0S9.

[10] Report 36, Ibid., Chapters 5 and 6.

enrolment at the senior secondary level will continue for several years, and some of the younger teachers (those with 8 to 10 years of experience) could be forced out. The Ontario system will be adjusting to the still-unknown effects of the extension of public funding to Grades 10 to 13 in the separate (Roman Catholic) schools, a development that is sure to put added stress on the present public system. It will be important to make provision, somehow, for new, well-educated science teachers to enter the system (public and separate) in the next few years, if the quality of education is to be maintained.

THE STUDENTS—A LARGE BUT SELECT GROUP

> Students with a high ability or special interest in science and technology should have program provisions made to encourage and challenge them to further inquiry.
>
> --major recommendation 3, Science Council Study, 1984.

The large number of instruments in the Field Trial (500 in Grade 12 and 300 in Grade 13) meant that a large number of students were required for the statistics on each instrument to be accurate. The occasion of the Field Trial was used to conduct a survey of student characteristics and attitudes and when the forms were finally tallied, there were 12,902 from students in Chemistry classes. This is far more than anyone would need for a survey,[11] so only a few questions were asked of all students—what grade they were in, their sex and age, the language spoken at home, whether they had a part-time job, the courses they were taking, and the sorts of plans they had for their future studies. Some questions were asked of half the students and still others of only a quarter. The result was that the smallest number ofresponses was over 3000, with few exceptions. The full set of questions is found in Appendix B.

The special character of this select group of students is revealed in the proportion planning to go on to post-secondary education. Seventy per cent plan to go to university and another 20 per cent to a college of applied arts and technology (CAAT). This is not surprising, of course, since these are students taking Grade 12 Chemistry at the advanced level or Grade 13 Chemistry, but it is worth stressing at the beginning so that one remembers not to generalize these results for all secondary school students. Perhaps the unexpected result is that 10 per cent of the students say they do not plan to go to university or a CAAT.

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[11]Public opinion polls across all of Canada normally have 1500 to 2000.

Just under 10 per cent of the students were early enrollees, that is, students in Grade 10 (only 32) or Grade 11 (1090) who were taking these Grade 12 or Grade 13 courses. These keen science students were university-bound (82 per cent) and planning on a science career (52 per cent) in slightly higher proportion than the sample as a whole. The percentage of females among early enrollees (47) was slightly higher than in the sample as a whole, as the next section will show.

Proportion of Females and Males

The low proportion of females taking advanced science courses has been a matter of concern in recent years. Although they provide no figures,[12] the authors of the Science Council of Canada study referred to in Chapter 1 made the second of their eight major recommendations on this question:

> Measures should be taken by educators to ensure that girls have improved opportunities and greater encouragement to participate fully in science and technology education (Report 36, p. 35).

The authors go on, "We have already noted with concern the low participation of girls in physical science courses in school and the negative consequences of this for their opportunities to pursue scientific and technological careers."

It was true that fewer females than males were found to be taking Chemistry in the 1983 survey, but the proportions were not as far apart as one might expect from the quotations above. The trend was not promising, however. In Grade 12, 46 per cent of the students were female but in Grade 13 the percentage dropped to 43. There were some differences between male and female responses, on the homework questions, for example, but for the most part these differences appeared negligible. Given the random assignment of achievement booklets and the diversity in content coverage, it was decided not to attempt a comparison of achievement between males and females.

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[12] Their reference is to Janet Ferguson (Ed.), Who Turns the Wheel?: Proceedings of a Workshop on the Science Education of Women. Science Council of Canada, 1982.

Language Spoken at Home

When asked about the language (or languages) spoken at home, 77 per cent chose the option, My family and I speak only English at home. There is cultural diversity, though, since 15 per cent of this select group chose, I usually speak English but my family speaks another language at home. Just under 10 per cent of the sample replied, My family and I speak a language other than English at home. It would thus appear that the first language was not English for about a quarter of the students in advanced Chemistry in 1983.

Future Plans

As was noted above, 90 per cent of these students plan to go on to study in university or a CAAT. A bare 2 per cent reported they would most likely look for a full-time job. In response to the statement, I intend to pursue a science-related career after leaving high school, only 28 per cent said no. Just over half (51 per cent) said yes.

Almost two-thirds of the Grade 12 students said that they planned to take Grade 13 Chemistry, and all are taking or plan to take additional courses in mathematics and the sciences. Students were asked, "Which of the following courses are you taking or do you plan to take in Grade 13?" The courses listed (and percentages of Grade 12 students taking or planning to take them) were: Algebra (46 per cent), Biology (54 per cent), Calculus (65 per cent), English (83 per cent), Relations and Functions (70 per cent) and Physics (52 per cent). Over 80 per cent of the Grade 13 students indicated that they were taking Calculus or Relations and Functions (or both).

As one would expect, students who opt for the advanced courses at the senior secondary level are doing so as preparation for further studies, and about two out of three plan to continue in that field. Among the students from non-English speaking homes, a substantially higher proportion definitely planned a science career (57 per cent vs. 49 per cent in homes where only English was spoken).

Females and males had very similar plans. The same proportion planned to go to university, and just 3 per cent more males said that they were headed for a CAAT. In passing, we might note that a different pattern was observed in Physics classes, where, though a higher proportion were male, many more of those planned to go on to a CAAT, with many more of the females planning to go on to university.[13]

Part-Time Jobs

Students were asked separately whether they had a part-time job after school and whether they had a part-time job on weekends. When responses to these questions were put together, they showed that 60 per cent had a part-time job sometime, and that 40 per cent worked both after school and on weekends.

The proportions of students reporting the four possible combinations are presented in Table 4, and the links between jobs, homework, and achievement will be discussed in subsequent sections. The pattern of part-time jobs was the same for males and females and across language groups; that is, about the same proportion of females as males worked both after school and on weekends, and the proportion was no different among those who spoke other than English at home.

TABLE 4

Pattern of Part-time Jobs Reported by Students
Numbers are percentages (N=6230)

		Weekends	
		Yes	No
After School	Yes	41	5
	No	15	39

[13] Results from the survey in Physics classes are found in the report by Les McLean, Teaching and Learning Physics in Ontario Grade 11 and 13 Classrooms. Toronto: Ontario Ministry of Education, in press.

Availability and Use of Computers and Calculators

Computers had barely begun to influence the teaching of Chemistry at the end of the school year 1982-83. Only about 1 student in 10 said that a computer was available for use in their Chemistry course, and even fewer said that they had used a computer in their study of Chemistry. This is another expected result, since microcomputers were just starting to appear in quantity in Ontario schools during that period, and most were in Mathematics and Computer Science courses. There are now many commercial programs available for use in Chemistry classes, but teachers are just beginning to find ways in which computers can help in teaching and learning.

A difference in perception turned up with regard to the availability of computers for Chemistry classes. Teachers were asked, "Is a computer available for use by your Chemistry classes?", and a third of them said yes, in both Grade 12 and Grade 13. It is easy to believe that the teachers were quite correct in their replies and that the students were quite sincere in theirs. A computer might well be available, if one knew where it was and how to use it, but it might seem unavailable if either condition were not met.

Calculators are another matter. Two-thirds of the students reported that they used a calculator frequently in their Chemistry course. Advanced scientific models have been common for some time, and, in many schools, students are required to have access to one. In this survey, therefore, we asked, "How often do you use a calculator in your Chemistry course?" About a third said, once in a while, a third every week, and a third every day. Those planning a career in science and those planning to go to university were more frequent users than the few who had other futures in mind. Students from homes where only English was spoken were also more frequent users, as can be seen in Table 5.

TABLE 5

Frequency of Use of Calculator in the Chemistry Course by Students from English and Non-English Speaking Homes

Language spoken at home	Frequency (% reporting) A little	Weekly	Daily	N
English	34	36	30	4882
Other	44	26	30	1432

Student Attitudes toward Chemistry and Science in General

The aims and objectives of science teaching include the following, all rated by senior secondary school teachers as important or highly important in the recent national study.[14]

- Understanding the role and significance of science in modern society
- Developing attitudes appropriate to scientific endeavour
- Relating science to career opportunities

In the survey, therefore, an effort was made to determine progress toward these three objectives, as well as progress toward content objectives. A thorough study of attitudes would include interviews and discussions with students, but, in such a large-scale survey, one must depend on written responses from the students. As will be seen below, the large sample of students yielded more stable results than usually obtained with this type of methodology.

[14] Science Council study—see Background Study 52, Vol. II, p. 53ff.

Inferring Attitudes

A group of 55 statements was prepared describing feelings or preferences students might have about Chemistry. Each student was given about a dozen of the statements and asked to indicate agreement or disagreement with each one.[15] For example, two of the statements were, I would like to spend more time doing experiments, and Man-made chemicals do more harm than good. All the statements may be found compiled in Appendix B.

The statements were assigned to booklets and the booklets were distributed to students in such a way that every pair of statements was presented to hundreds of students. It was then possible to calculate the correlations between every pair of the 55 statements (1485 correlations) and use the method of factor analysis to look for groups of statements representing common themes.[16]

These common themes, or factors, are interpreted as beliefs or attitudes underlying the overt responses students made to the statements. Attitudes are psychological constructs and, as such, are not directly observable. They must be inferred, and the present method is a common way of doing so. It is rare, however, that a study has so many participants and hence can try so many statements and still have stable estimates of the correlations.

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[15] A five-point scale was used: "strongly disagree", "disagree", "undecided", "agree", "strongly agree".

[16] I am indebted to Professor R. Traub for the factor analysis. Because the same statements were given to both Chemistry and Physics students (changing only the word Chemistry to Physics where necessary), almost 40,000 student responses were available. These responses were first divided into two approximately equal groups in a stratified random way that made them equivalent (in the statistical sense). Correlation matrices were calculated for each group, and the second was used to confirm the pattern found in the first. Prof. Traub used various techniques to decide that a five-factor solution fit the data best, and five factors were submitted to orthogonal rotation (Saunders' equimax solution). When the same techniques were applied to the second sample, the two solutions were remarkably similar. Coefficients of concordance were .989, .975, .991, .941 and .867, indicating a robust factor solution.

The five factors all had sensible interpretations, lending more credibility to the attitudes thus identified:

Factor I — Attitude toward experiments. A positive attitude is indicated by agreement with statements 30, 31, 32, 35, 36, 37, 46, and 62, and disagreement with statements 25-29, and 50 (see Appendix B). (28: I would like to spend more time doing experiments. (23: I prefer to read why things happen rather than to do an experiment to find out.)

Results: Positive. Agreement average 3.80, disagreement average 2.17, where 5 = strongly agree, 1 = strongly disagree.[17]

Factor II — Approval of science as an area of human activity, especially Chemistry. Agreement with statements 61, 63, 65, 66, 79-89 and 91 indicates an attitude that science is important, both to the individual and to society. (81: Chemistry will play an important role in our country's development. (87: Chemistry has improved our standard of living.)

Results: Very positive. Agreement average 3.91.

Factor III — Learning science outside the classroom. Ten statements described activities such as reading magazines, watching science programs on television, and the like. Students who agree with these statements derive enjoyment from learning about science through leisure activities. (54: I like to visit science museums. 55: I would like to belong to a science club. 91: More scientists should do demonstrations on T.V.)

Results: Mixed, but positive on balance. Agreement average 3.23.

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[17] The average across items of average student response is only the roughest of indicators. The proper summary would be factor scores, but that would have required much labour and computer time that didn't seem warranted in view of the clarity of the results.

Factor IV Finding science easy and enjoyable to learn. Students who agree with statements such as 57: <u>Chemistry lessons are fun</u>, and disagree with 66: <u>Chemistry is harder for me than it is for most other people</u>, clearly find the study of Chemistry more of a pleasure than those who disagree. This factor was also defined by statement 89: <u>So far, there have been more good outcomes of Chemistry than bad ones</u> (agreement), and statement 69: <u>I find Biology the easiest of the science courses</u> (disagreement). No doubt about it—this self-selected group of university-bound teenagers is keen on science!
Results: Positive. Agreement average 3.4, disagreement average 2.85.

Factor V Financial support for science. Agreement was general with 83: <u>Money spent on scientific research and development is money well spent,</u> and 84: <u>Money spent applying the results of scientific research is money well spent</u>, and disagreed with 88: <u>Man-made chemicals do more harm than good</u>. The same pattern of agreement was found with 45: <u>I enjoy reading about science in books and magazines,</u> suggesting that the factor reflects more general support than just agreement with financial support for science. (As would be expected, statement 45 was related to Factor III even more strongly than to Factor V. Statements 85 and 86 were also related to Factor II, but the statistical evidence pointed strongly to the existence of the fifth factor, separate from Factors II and III.)
Results: Positive. Agreement average 3.87, disagreement average 2.6.

<u>Interpreting Attitudes</u>

The factors one finds are determined by the statements one puts before the students, of course, and the list used in this study reflects the strong interest of the Advisory Committee in the role of experiments in teaching and learning, the status and importance of science (especially Chemistry) in society, and the feelings students

have toward the study of science. The list of statements was collected from other studies before any news was available of the Science Council study, but the overlap of interest is great. Several of the statements (e.g., 25-37, 48-50) fit easily under the heading, "Attitudes Appropriate to Scientific Endeavour," and others under "The Significance and Role of Science in Today's Society."

A point worth stressing is that the aims and objectives mentioned at the beginning of this section are aims and objectives in their own right; that is, they are not simply means toward higher scores on achievement measures. Some researchers have reported weak links between attitudes and achievement, but a recent comprehensive review (Willson, 1983) concluded that the evidence is too meagre to believe either that attitudes cause achievement or the reverse.

> Contrary to a recent published review there does not appear to be a consistent cross-age causal direction between attitude and achievement. At elementary and junior high levels there is higher correlation for achievement causing attitude than for attitude causing achievement. This is reversed for senior high and college levels, but at no levels were results statistically significant (p. 849).

There is often a fine psychological line between attitude and interest. How, for example, do we classify statement 59: I really want to do well in Chemistry? How about 54: I like to visit science museums? More important, are these (as argued above and in the Science Council study) legitimate aims and objectives of teaching? The author of the comprehensive review mentioned above (Willson, 1983) has doubts:

> Perhaps science curricula should concentrate on achievement and let the affect follow without curricular emphasis. For science interest the same case might be made. Educators should not care what the simultaneous correlation between achievement and attitude is; they should care about the attitude of children after their science experience. Successful achievement will cause positive attitude, if these data are to be believed (p. 849).

This point of view might be valid for certain measures sometimes called "psychologically scaled attitude," but it does not seem appropriate for the objective: understanding the role and significance of science in modern society. Attainment of that objective requires inclusion of appropriate content in the curriculum. The Science Council researchers found that teachers (reflecting provincial guidelines) uniformly gave low importance to developing an awareness of the practice of science in Canada. If one goal is to portray science as part of the cultural fabric of Canadian society, then Canadian science will have to be part of the content of the curriculum. There need be no conflict with achievement goals, because selection and discussion of Canadian examples would likely suffice. The present survey supports the view that successful achievement (as represented by these students' voluntarily taking the advanced courses) leads to positive attitudes (expressed by almost all students).

THE MANY CHEMISTRY COURSES

> . . . a number of dilemmas face teachers of the separate sciences. Central to their work is a tension between "covering" the required and considerable subject matter so as to lay the foundation for future work, and promoting student interest in that work through an inquiry method that takes time, that can be difficult to evaluate, and that is problematic in its own right. While the subject matter to be covered is specified by official documents and by texts—and these are followed closely—the ways in which this content can be made interesting and relevant to students is a matter of some uncertainty for the teachers of the senior grades.
>
> --John Olson and Thomas Russell, 1984.

As was noted in Chapter 1, teachers make independent choices of what topics to teach and how to teach them, within the very general guideline provided by the Ministry of Education. In 1983, the influence of the guideline was much reduced, because it had not been revised for many years and everyone knew that a new guideline was imminent. By their very nature, however, these guidelines are just that, guides. Schools prepare more specific Courses of Study, tasks that would be done by Department Heads and members of the department in most secondary schools. Even then, individual teachers have many important decisions to make, and the evidence shows that no two teachers make the same decisions.

In this chapter, more details are provided about the topics teachers choose and the emphasis they give to them. The prerequisites that teachers feel students should have are analyzed. A closer look will be given to the percentage of time teachers report students spending on activities, and student attitudes toward a number of aspects of Chemistry and science will be explored. Finally, the resources and safety equipment available to teachers are noted.

Chemistry Course Content

The topic descriptors for the Grade 12 and 13 courses were taken from the Chemistry OAIP, which in turn were taken from the guidelines (S-17D and S-17E). As noted in Chapter 1, the guidelines were rather old at the time of the Field Trial, and about 10 per cent of the teachers wrote on their questionnaires that they did not break down their teaching according to those topics, nor did they think in terms of hours (as requested in the questionnaire). These teachers did answer as requested, but said their responses were only approximate. It would seem only prudent to treat all responses as approximate, and to use them to indicate major trends and emphases.

The Grade 12 Course

Eleven topics were listed, each of which had at least one instrument included in the Field Trial. These are reproduced in Table 6, with median number of hours reported by teachers in year-long and half-year classes. Table 6 does not show in any way the range of times teachers reported, several examples of which were presented in Figure 1. The box-and-whisker graphs are presented in Figure 2, where it can be seen that even the least-taught topics (Elements of Groups 2 and 7) were taken up by some teachers and six or more hours spent on them.

There was little or no common pattern to the teachers' choices, though there was some tendency for teachers who spent more time on one of the first four to spend more time on the other three of that group (and vice versa—less time on one, then less time on the others). This weak pattern (or lack of a pattern, perhaps) is reflected in the correlations among the teacher times (see Table 7). The largest correlation but one (0.45) is between two heavily taught topics, The Mole,... and Formulas, Nomenclature... The large figure for the two Elements topics is suspect, because so few teachers taught these topics, but it does appear that, if a teacher teaches Group 2, then the teacher also teaches Group 7.

TABLE 6

Grade 12 Chemistry Topics and Associated Statistics for Correlation between Achievement and Opportunity to Learn (OTL), Mean OTL, Median Number of Hours Devoted to the Topic, Average and Standard Deviation of Classroom Achievement Means.
OTL Scale: 1 = not taught, 2 = taught before, 3 = taught this year

Topic	Ach OTL	Mean OTL	Med. Hours	Mean Ach.	S.D Ach.
Structure of Atoms (Unit 2)	0.37	2.6	6	0.53	0.13
Structure of Aggregate Atoms (Unit 3)	0.33	2.5	5	0.45	0.11
States of Matter and Gas Laws (Unit 4)	0.47	2.3	9	0.48	0.11
Oxygen and Hydrogen (Unit 5)	0.29	2.3	3	0.51	0.11
The Mole, Atomic Weight, Molecular Weights (Unit 6)	0.60	2.6	10	0.55	0.12
Formulas, Nomenclature and Equations (Unit 7)	0.38	2.6	10	0.52	0.11
Water and Solutions (Unit 8)	0.31	2.2	4	0.45	0.11
Ions in Aqueous Solution (Unit 9)	0.37	2.2	3	0.41	0.11
Elements of Group 2 (Unit 10)					
Elements of Group 7 (Unit 11)					
Periodic Classification of Elements (Unit 12)	0.50	2.4	4	0.46	0.09

Figure 2: Box-and-Whisker graphs showing the range of time (number of hours) teachers reported spending on Grade 12 topics. The topics not shown here were shown in Figure 1.

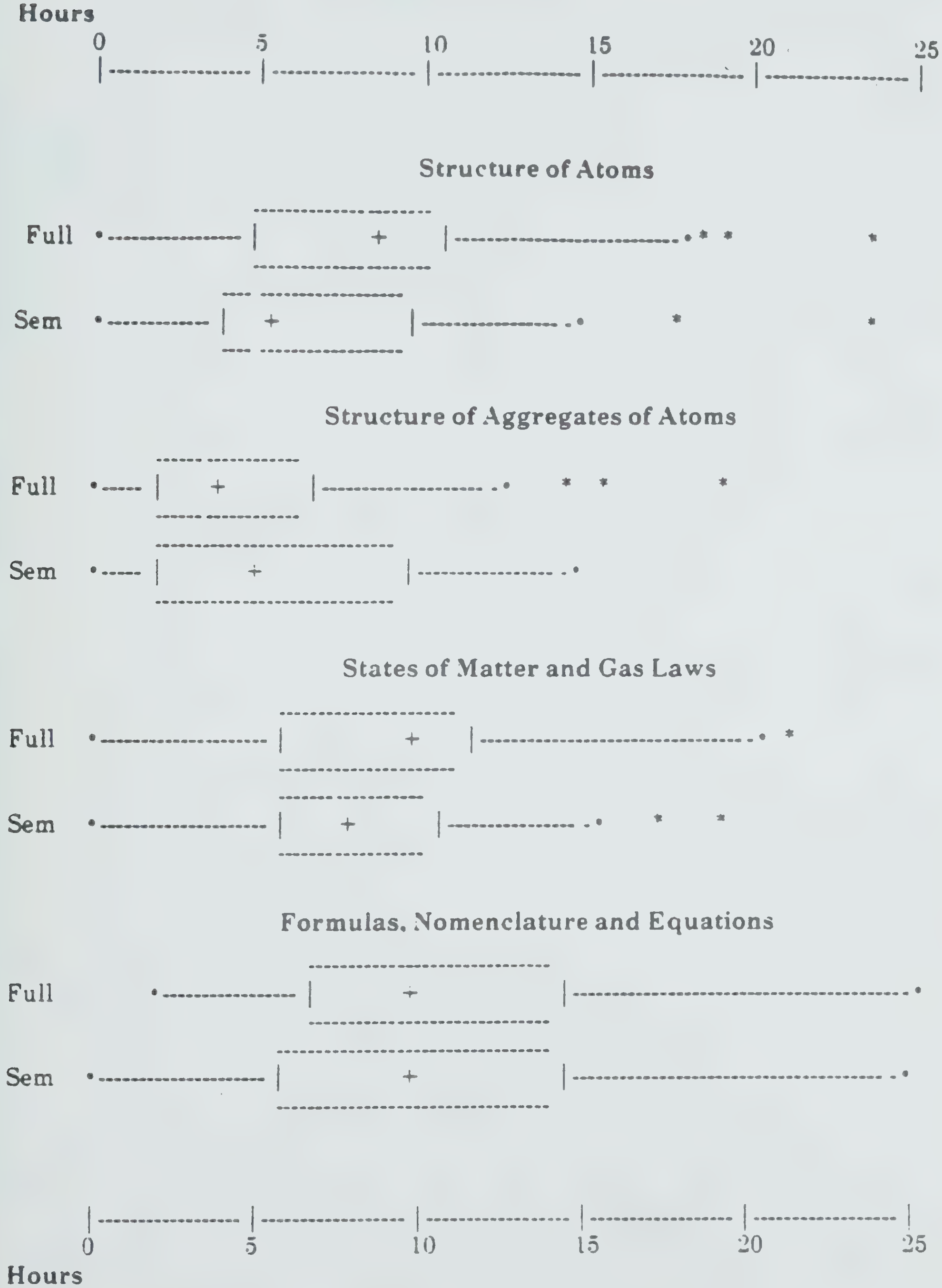


Figure 2 cont.

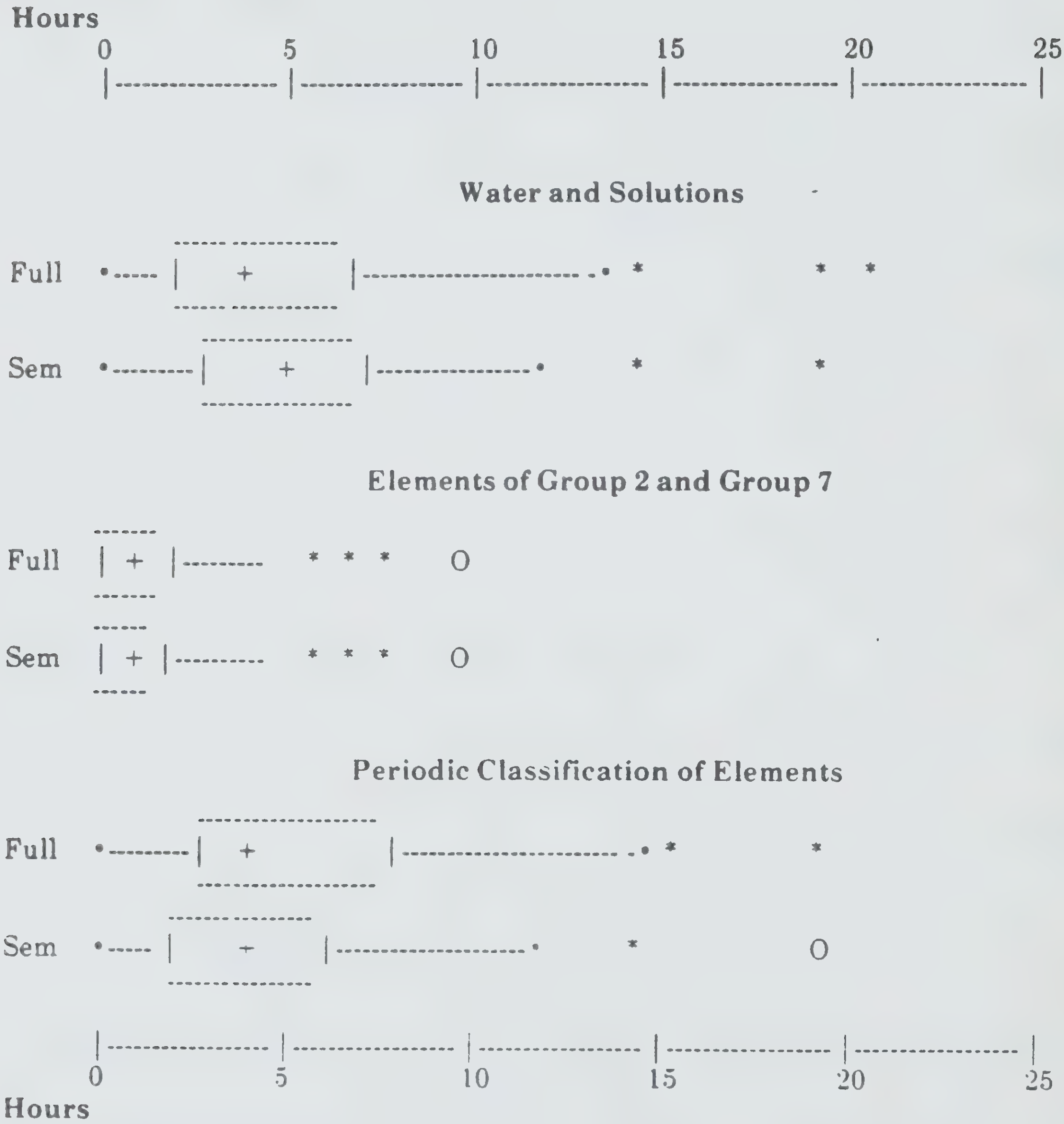


TABLE 7

Correlations Among the Times Spent on Topics
by Grade 12 Teachers

	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7	Unit 8	Unit 9	Unit 10	Unit 11
Unit 3	0.32									
Unit 4	0.38	0.29								
Unit 5	0.24	0.25	0.20							
Unit 6	0.25	-	0.31	-						
Unit 7	0.29	-	0.33	-	0.45					
Unit 8	-	-	-	0.25	0.24	0.30				
Unit 9	-	-	-	-	0.22	-	0.29			
Unit 10	-	-	-	-	-	-	-	-		
Unit 11	-	-	-	0.21	-	-	-	0.24	0.72	
Unit 12	0.27	-	0.23	-	0.39	0.42	0.27	-	-	-

A teacher wrote, "We cover all topics in the course of study at the rate at which that particular class and student can accomplish them." Clearly, the classroom teacher has to make that judgment and, just as clearly, any two teachers might not agree on the best rate for a given class. The result is the diversity we see.

The number of instruments included in the Field Trial for each topic was set to correspond roughly to the emphasis that topic receives in the guideline and in practice, according to the Advisory Committee.

Each instrument in the student booklets had two parts—the instrument itself (multiple choice—four alternatives) and a question about <u>opportunity to learn</u>. The latter asked students to choose only one of three options, "Not taught," "Taught before," or "Taught this year." These were coded 1, 2, or 3, as representing more and more opportunity for the student to learn the material.[18] The average across all classes of this <u>student OTL</u> is listed alongside the teacher

[18]This technique was developed for the Second International Mathematics Study (McLean, Raphael, & Wahlstrom, in press) and was employed in the 1981 field trials in English and mathematics (McLean, 1982). When aggregated to the class level over several instruments in the same topic the measure has been shown to be an accurate reflection of teaching emphasis and to be positively correlated with student achievement.

reports of time spent (teacher OTL) in Table 6, and one can see that there is good agreement at least on relative emphasis. The exception is Unit 4, where the students rated their opportunity to learn rather low (2.3, nearer to the value "Taught before") in comparison to Units 6 and 7, all of which were given comparable time (lots of it) according to the teachers.

There could be many good reasons for this discrepancy, including the teachers' interpretation of States of Matter and Gas Laws. The overall agreement is somewhat amazing, since the students were rating instruments (achievement items) and the teachers abstract categories. When student OTL was correlated with student achievement (classroom averages), all correlations were positive and statistically significant (see Table 6). The smallest was 0.29 (for Unit 5) and the largest 0.60 (for Unit 6). As would be expected, there is a strong link between what is taught (and for how long) and what is learned. Readers interested in the full report on student achievement, instrument by instrument, may consult the document, Report of the 1983 Field Trials in Chemistry, Senior Division and Grade 13.

The Grade 13 Course

The 300 OAIP instruments included in the booklets given to Grade 13 students in the field trial were coded to 14 topics, as listed in Table 8. Partly because it is so rarely taught, there are few items in the Chemistry OAIP coded to Unit 13, 3rd Row of the Periodic Table. Units 8, 14, and 15 were also rarely taught (note that the median number of hours is zero). There were very few instruments in the Field Trial for Unit 8, because it is difficult to test with multiple-choice instruments.

The range of hours reported by Grade 13 teachers was as great as or greater than that for Grade 12, so no box-and-whisker summaries are presented. With the exception of Unit 12, the median time devoted to topics was nearly the same in year-long as in half-year classes. For 11 of the 15 topics, the spread (length of the box) for year-long classes was equal to or greater than the spread for half-year classes. Packing the course into a half year appears to constrain the variation somewhat.

TABLE 8

Grade 13 Chemistry Topics and Associated Statistics for Correlation between Achievement and Opportunity to Learn (OTL) Mean OTL, Median Number of Hours Devoted to the Topic, Average and Standard Deviation of Classroom Achievement Means.

OTL Scale: 1 = not taught, 2 = taught before, 3 = taught this year

Topic	Ach OTL	Mean OTL	Med. Hours	Mean Ach.	S.D. Ach.
Energy Effects in Chemical Reactions (Unit 2)	0.18	2.6	10	0.52	0.12
Rates of Chemical Reactions (Unit 3)	0.20	2.7	10	0.58	0.11
Equilibrium in Chemical Reactions (Unit 4)	0.43	2.8	11	0.55	0.13
Solubility Equilibria (Unit 5)	0.08	2.5	7	0.61	0.14
Aqueous Acids and Bases (Unit 6)	0.44	2.5	11	0.50	0.12
Oxidation-Reduction Reactions (Unit 7)	0.60	2.3	10	0.50	0.14
Experimental Base for Atomic Theory (Unit 8)			1		
Electron Arrangement and the Periodic Table (Unit 9)	0.49	2.2	2	0.48	0.12
Molecules in the Gas Phase (Unit 10)	0.36	2.1	1	0.45	0.13
Bonding in Solids and Liquids (Unit 11)	0.29	2.1	2	0.51	0.14
Chemistry of Carbon Compounds (Unit 12)	0.55	2.0	5	0.50	0.18
3rd Row of the Periodic Table (Unit 13)					
4th Row Transition Elements (Unit 14)					
Some 6th and 7th Row Elements (Unit 15)	0.40	1.9	0	0.46	0.17

There was more pattern to teachers' choices in Grade 13 than in Grade 12. As can be seen from the correlations in Table 9, Units 2 through 7 form a block of topics taught together a lot or a little, and Units 8 through 11 another block. As with the seldom-taught Grade 12 topics, Units 13, 14 and 15 are often taught together, if they are taught at all. That leaves Unit 12, Chemistry of Carbon Compounds, somewhat of a free spirit. This topic is given almost twice as many hours in year-long as in half-year classes, but the time given to it is not related in any consistent way to the time given to other topics. The students reported that they had been taught the material needed to answer the Unit 12 instruments before their Grade 13 year (OTL average 2.0).

TABLE 9

Correlations Among the Times Spent on Topics By Grade 13 Teachers

	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
Unit 3	0.74				
Unit 4	0.58	0.66			
Unit 5	0.46	0.53	0.43		
Unit 6	0.53	0.49	0.61	0.49	
Unit 7	0.47	0.45	0.49	0.34	0.53
Unit 8	-0.21				

	Unit 8	Unit 9	Unit 10	Unit 11	Unit 12	Unit 13	Unit 14
Unit 9	0.42						
Unit 10	0.42	0.43					
Unit 11	0.20	0.36	0.49				
Unit 12	-	-	-	-			
Unit 13	-	-	0.24	0.23	-		
Unit 14	-	-	0.20	-	-	0.46	
Unit 15	-	-	-	-	-	0.32	0.30

The link between teaching and learning was more variable in Grade 13 classes than in Grade 12. As noted in Table 8, the correlations between student OTL and achievement are low for Units 2, 3, and 5, even though there is agreement between student and teacher OTL. On the other hand, there are strong correlations for the other topics, including our free spirit, Unit 12.

Time on Experiments and Other Activities; Problems in Class

Another way to look at teaching is to examine the activities teachers use in covering the content. In Chemistry, of course, experiments play an important part. From other such surveys, and with help from the Advisory Committee, a list of activities was presented, and teachers were asked to estimate what percentage of class time students spent on them. A residual category was provided, and a total of 100 per cent was indicated. This was the final section of the 10-page questionnaire and, as noted in Chapter 1, it appeared that many teachers did not take the time to make their responses add to 100. One teacher wrote, "It took me longer to do this than it took the students to do the test."

However, the averages add almost exactly to 100 per cent, so these are reported in Table 10. Doing, discussing, graphing, and writing up experiments and doing problems in class account for about 60 per cent of class time, and, when the residual category is added (tests, other teaching activities, etc.) very little time is left. As mentioned in Chapter 1, however, there was great diversity among teachers in the ways they divided time among these activities. Because of the large range, the average (arithmetic mean) is not a very good indicator for individual teachers.

TABLE 10

Average Percentages of Time Students Spent on Activities, According to Teacher Reports

Activity	Grade 12	Grade 13
Doing experiments	22.0	19.0
Discussing experiments	9.7	8.9
Making graphs from experimental data	3.2	2.5
Writing up experiments (describing/ reporting experimental observations	6.6	5.5
Discussing scientific issues and values	6.4	6.0
Watching teacher demonstrations	5.5	5.2
Doing problems in class	18.5	20.8
Watching films, videotapes	4.3	4.7
Doing computer activities	0.4	0.5
Other	22.9	25.9

One way to communicate the diversity is to show some of the time profiles reported by individual teachers. In Table 11, reports from 16 teachers are summarized, combining the first four categories under Experiment Time and the two, "Watching" and "Doing computer activities," (because it was so small) under Watch Time. The teacher reports were taken from those with a total near 100, choosing quite arbitrarily all those reporting spending between 51 and 60 per cent of their time on experiment-related activities.

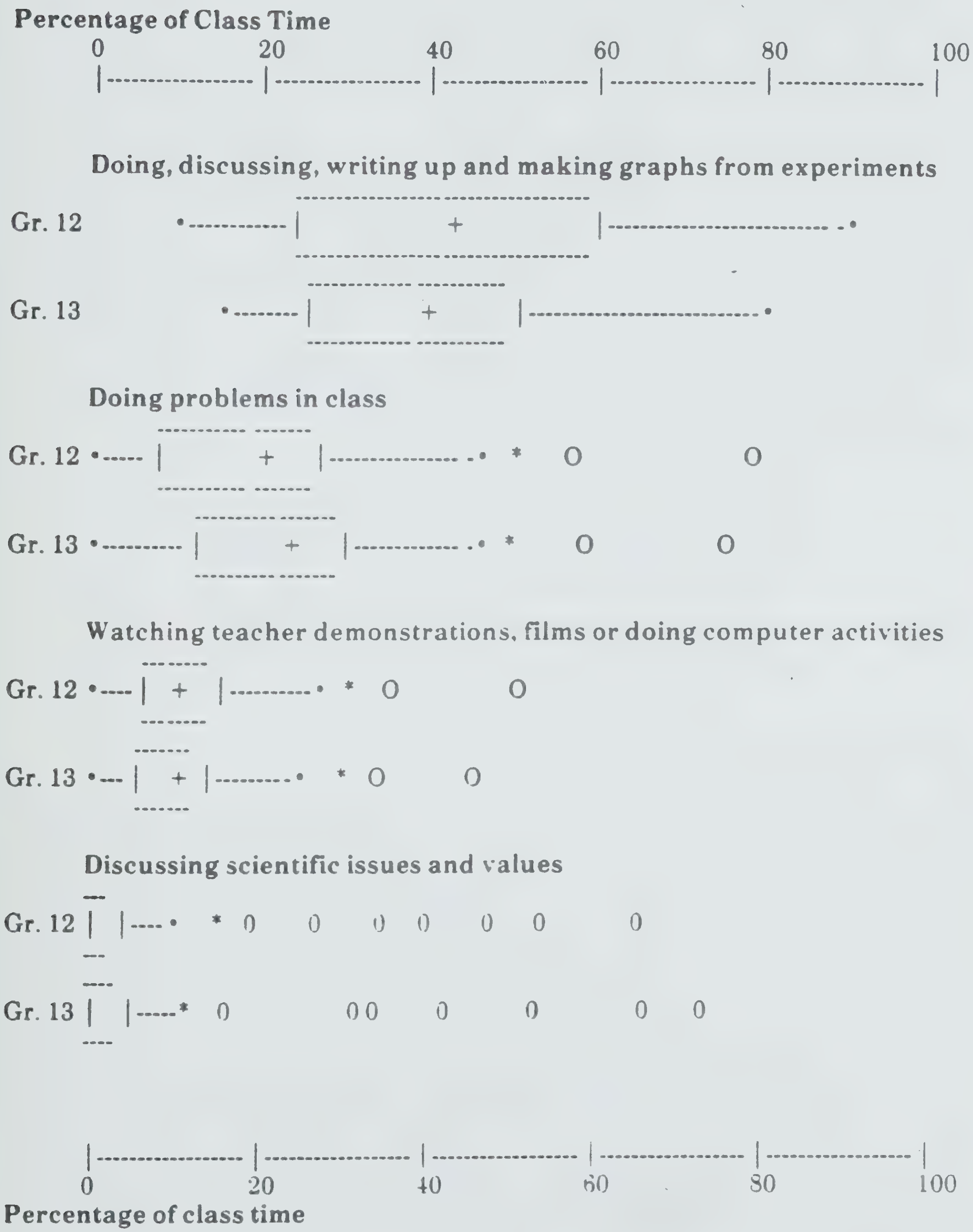
TABLE 11

Examples of Reports from 16 Grade 12 Teachers of Percentages of Time Students Spend on Activities

Experiment Time	Discuss Time	Watch Time	Problem Time	Other Time
60	5	10	25	0
60	2	9	15	14
60	2	13	25	0
60	5	10	25	0
60	0	15	25	0
60	5	15	20	0
58	35	7	0	0
57	1	16	25	0
56	1	6	25	12
55	0	10	10	25
55	25	10	19	0
55	5	10	20	10
55	4	21	20	0
52	1	8	5	34
51	6	12	15	20
51	28	14	5	2

Results from all the teachers are summarized in Figure 3. The summaries show clearly how conducting experiments and doing problems dominate classroom time. Three-quarters of the teachers reported that the students spent less than 5 per cent of instructional time discussing scientific issues and values. One teacher wrote, "The rigorous demands of the curriculum content permit little time for

Figure 3: Distributions of percentages of time chemistry teachers reported students spending on experiments, doing problems in class, discussing, watching and the rest



discussion of scientific issues and values, although that would be a welcome addition to the curriculum." That teacher's view was consistent with the Science Council study discussed earlier, where a concern was expressed that there were too many topics in the curriculum. Teachers across Canada said that "Understanding the role and significance of science in modern society" was very important in both the middle and senior years, but it has been difficult to displace scientific content to make room for more global objectives.[19]

The time spent doing problems in class is augmented by homework. Students reported spending, on average, 42 per cent of their homework time "doing problem exercises," as compared with 22 per cent "writing up lab reports" and 17 per cent "reading sections out of the textbook." This pattern is apparently pervasive, as indicated in this quotation from an article entitled, "Enriching Formal Knowledge: A Model for Learning to Solve Textbook Physics Problems."[20]

> Individuals who have become skilful in such tasks usually report a relatively small amount of time spent studying textual materials or listening to lectures, but a much larger amount of time spent practising solving problems (p. 311).

Emphasis on Objectives

Yet another perspective on teaching is the emphasis teachers give to various objectives. An objective can be very detailed or very general, and it is difficult to settle on a level of abstraction that is meaningful to most people. Teachers were presented with 31

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[19] See, for example, Background Study 52, Vol. II, p. 83. The importance of science-and-society objectives is discussed on p. 54.

[20] J. H. Larkin, "Enriching Formal Knowledge: A Model for Learning to Solve Textbook Physics Problems." Chapter 10 in J. E. Anderson (Ed.), Cognitive Skills and Their Acquisition. Hillside, N.J.: Lawrence Erlbaum Associates.

objective statements ranging from Developing questioning skills to taking careful measurements, and were asked, "To what extent do you emphasize the following objectives in your Chemistry classes?" A five-point scale was provided for their response:

1	2	3	4	5
Not at all	To a small extent	To some extent	To a significant extent	To a great extent

Fifteen of these objectives relate directly or closely to experiments, and are discussed in Section 4. Summary results on the remaining 16 are presented in Table 12, with some objectives repeated in both chapters for comparison. With few exceptions, Grade 12 and 13 teachers gave the same responses.

The image of science and science teaching implied by these responses is consistent with the findings of the study carried out by the Science Council researchers, and this image will be discussed in the next chapter.

Courses Students Should Take Prior to or Along with Chemistry

There has been considerable debate as to whether students should be required to take certain mathematics or science courses before being eligible to take senior division Chemistry. At the time of the Field Trial, no such requirements were in the guideline or in provincial regulations. Schools set up certain requirements and counsel students to take certain sequences, but students presenting themselves for Grade 13 Chemistry may not legally be turned away if they are in good standing in the school. As already noted, students in earlier grades enrol in Grades 12 and 13 Chemistry. Some teachers reported that up to 50 per cent of their Grade 13 Chemistry students were registered in Grade 12 (although three-quarters of the teachers reported 20 per cent or fewer).

TABLE 12

Amount of Emphasis Given by Grade 12 and Grade 13 Chemistry Teachers to General Course Objectives*

This table tells us:

Safety, discipline, and terminology were dominant objectives for these teachers.

Objectives teachers emphasize most

Following proper safety precautions in a lab (4.55)
Understanding of the need to be cautious when handling chemicals (4.49)

Objectives teachers emphasize to a significant extent

Learning science concepts (4.12)
Taking careful measurements (4.09)
Recognizing and understanding scientific terms (4.09)
Using scientific terminology and conventions (4.06)
Understanding information presented in symbolic form (3.99)

Objectives teachers emphasize to some extent

Developing an appreciation for chemistry (3.71)
Understanding science as a highly unified and consistent view of the world rather than a collection of isolated facts (3.64)
Reading and interpreting graphs--Grade 13 (3.54)

Understanding the value and limitations of physical laws (3.42)
Reading and interpreting graphs--Grade 12 (3.37)
Developing questioning skills (3.29)

Relating science to career opportunities (2.93)

Objectives teachers emphasize hardly at all

Studying experiments for flaws (2.62)
Designing experiments (2.30)

*Responses on objectives related to experiments are presented in Table 13.

Teachers were asked, "Which of the following subjects do you think a student should take prior to or along with your course?" An exhaustive list of secondary science and mathematics courses was presented, plus a residual category, <u>other</u>. It was therefore possible to tabulate the joint preferences teachers had; for example, how many students wanting Grade 11 Mathematics also wanted Grade 11 Physics, and so on. From this table of joint preferences, a clear pattern emerges of the courses teachers think students should take. This survey was done before the latest reorganization plan, Ontario Schools Intermediate and Secondary (OSIS), was tabled, and the responses would very likely be different now.

Grade 12 Chemistry teachers are agreed (90 per cent) that students should take Mathematics in Grades 9, 10, and 11, and Physical Sciences in Grades 9 and 10. Fewer than half think that Grade 9 and 10 Biological Sciences should be required. Grade 11 Physics is in the middle: three-quarters of the teachers said their Chemistry students should take it. Just under half (47 per cent) thought that students should take Grade 12 Mathematics along with the Grade 12 Chemistry. Thus, a majority would have been satisfied if 9-11 Mathematics, 9-10 Physical Sciences, and 11 Physics were set out as prerequisites. The biological sciences and Grade 12 mathematics would not be required. Such a pattern could be consistent with OSIS, but it certainly would limit the students' choice of options.

The same pattern of preferences was found among Grade 13 teachers, as regards courses in Grades 9 to 11. It will come as no surprise to most readers that 98 per cent of Grade 13 Chemistry teachers thought that students should take Grade 12 Chemistry. The Grade 13 teachers (83 per cent) thought students should take Grade 12 Mathematics. So far as concurrent courses went, few thought students should take Biology or Physics or the Grade 13 Mathematics courses (Algebra, Relations and Functions, and Calculus) along with Chemistry. If one were drawing up rules on the basis of this survey (going well beyond its purpose), Grade 12 Chemistry would be required for students taking Grade 13 Chemistry, and students in Grade 12 would be strongly advised to take Grade 12 Mathematics if they planned to go on to take Chemistry

in Grade 13. They would be advised that the rest of the Grade 13 courses (soon to be Ontario Academic Courses) were optional, so far as Chemistry teachers were concerned. This pattern, too, would be consistent with OSIS.

Science Teaching Resources and Safety Equipment

A large majority of schools are well equipped for teaching science, according to the teachers. Of 15 items, including storage space, sinks, and ventilation, only four were rated as inadequate by more than about a quarter of the teachers. (For the complete list, see Appendix A.) The four rated inadequate (percentage in parentheses) were:

1. Storage space for student projects (59%)
2. Ventilation (59%)
3. Fume hood/closet (55%)
4. Storage space for volatile liquids (41%).

There was a difference of opinion about storage space for student projects, since 15 per cent of the teachers said such space was not required. Between 15 and 20 per cent of the teachers reported that their water, sinks, and electricity and gas outlets were better than adequate.

Safety equipment was even more in evidence. Not a single teacher agreed with I have no safety equipment, and most equipment was on hand in 80 to 90 per cent of classrooms. The survey team was quite rightly criticized for asking whether teachers had asbestos gloves, since these are banned. Teachers substituted flame-proof gloves on many forms. Only a quarter had acid spill clean-up kits, and fewer than one in five had sand buckets and scoops. Virtually 100 per cent (but not quite) had a fire extinguisher, a master gas shut-off, and safety goggles.

One member of the Advisory Committee observed that these results were not too surprising, because many of these schools had been built in the last 10 to 15 years, when awareness was high and funds were

available. One wonders what the Chemistry teachers do in the 10 per cent of schools where the electricity outlets or water supply are inadequate or unavailable (in portable classrooms, for example).

EXPERIMENTS—IMPORTANT, POPULAR

La Chimie crée son objet

--Marcelin Berthelot, 1860.

Experiments play an important role in the teaching and learning of Chemistry. Teachers devote a considerable proportion of class time to doing and discussing them, and students both like and value them as a way of learning. These findings were quite clear in both the teacher and student responses on the questionnaires, a large part of which were devoted to experiments in one way or another.

Teaching Time and Emphasis

As noted in Chapter 3, teachers were asked what percentage of class time they spent on various activities, among them doing experiments, discussing experiments, making graphs from experimental data and writing up experiments. When the four categories were combined, the median in Grade 12 was 46 per cent of teaching time, and in Grade 13 it was 39. In other words, in Grade 12, half of the teachers said their classes spent at least 46 per cent of their time doing, discussing, or writing up experiments. A quarter of the teachers said that 60 to 80 per cent of the time was spent in this way.

Looking at the four categories separately, about 20 per cent of the time was spent doing experiments, with less than 5 per cent (on average) making graphs from experimental data. Discussing experiments accounted for another 10 per cent. Somewhere between 5 and 10 per cent of class time was devoted to writing up experiments. One implication of these responses is that very little time is spent making graphs and writing up results, an implication that is supported by other reports. For comparison, the midrange of percentages[21] of time doing problems in class in Grade 12 was 11 to 29, and the median 17. When we look at homework (next chapter), we will see that not much homework time is spent on experiments.

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[21] The midrange covers the middle half of teachers, that is, from the 25th to the 75th percentile. One-quarter of the responses from teachers fell below the midrange and one-quarter above.

We can get some insight into the teachers' motivation in spending this time by examining their responses to another part of the teacher questionnaire. In section VIII, 31 different objectives were listed, and teachers were asked, "To what extent do you emphasize the following objectives in your Chemistry classes?"[22] Among these objectives, seven could be linked directly to experiments and another 10 indirectly. So far as the amount of emphasis is concerned, there was almost perfect agreement between Grade 12 and Grade 13 teachers.

Only three objectives were emphasized to a great extent:

- Developing a systematic approach to problem solving.
- Understanding the need to be cautious when handling chemicals.
- Following proper safety precautions in a lab.

Two objectives were emphasized very little (to some or to a small extent) by two-thirds of the teachers:

- Designing experiments.
- Studying experiments for flaws.

Providing extensive experience with laboratory equipment ranked above Using graphs to present results from experiments and Incorporating controls in an experiment (among objectives emphasized to some extent). Details of the responses are presented in Table 13.

What comes out is that teachers are concerned most with safety and with following directions. Scientific inquiry is lower on their list of priorities. Objectives emphasized only a little (to some extent) are incorporating controls in an experiment, Verifying results, and Using graphs to present results from experiments. Well above these (emphasized to a significant extent) were Carrying out instructions carefully and Taking careful measurements.

[22] A five-point scale was given, from "not at all" to "a great extent."

TABLE 13

Amount of Emphasis on Objectives Related to Experiments in Chemistry Classes

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This table tells us:

In their laboratory work, teachers are concerned that students follow instructions, do what they are told and work safely. Exploration, hypothesis testing and other aspects of scientific inquiry are farther down on the list.

Objectives teachers emphasize most

Following proper safety precautions in a lab (4.55)
Understanding of the need to be cautious when handling chemicals (4.49)

Objectives teachers emphasize to a significant extent

Carrying out instructions carefully (4.14)
Taking careful measurements (4.09)
Recognizing patterns in observations and data (4.04)
Presenting observations in written form (3.98)
Drawing and supporting conclusions (3.93)

Observing chemical similiarities and differences (3.85)
Making generalizations on the basis of results or observations (3.80)
Providing extensive experience with laboratory equipment (3.80)

Objectives teachers emphasize to some extent

Verifying results (3.54)
Using graphs to present results from experiments (3.41)

Incorporating controls in an experiment (3.21)*

Objectives teachers emphasize hardly at all

Studying experiments for flaws in design (2.62)*
Designing experiments (2.24)*

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*Emphasized slightly more in Grade 13 than in Grade 12.

This emphasis on orderly routine is not unique to Ontario, as the Science Council study made clear. In their summary, the researchers who visited and observed extensively in secondary schools across Canada offered these comments:[23]

> These teachers view science as a method of precision, characterized by exact numbers and highly organized bodies of information with specialized terminology (p. 22)
>
> Where they occur, alternative approaches, such as stressing inquiry processes, relating science to social issues, or relating science and technology, are seen not as central activities for the science classroom but as a means of encouraging students' interest (p. 22).
>
> Allied to the search for "right" answers in the lab is the work students do on problems in physics and chemistry. The way teachers view this "problem solving" activity also indicates how they view the nature of science. At Derrick High[24], chemistry students spend considerable time working out problems in order to apply principles and get correct answers (p. 23).
>
> Physical science, for example, is presented as a body of knowledge based on careful, precise observation whose conclusions are justified by that precision. Science is seen as yielding mathematical formulations that can be used to process data in order to obtain precise numbers that describe the physical world. Biological science is seen as less precise, but still yielding organized knowledge in the form of taxonomies and terminology (p. 23).

These observations were made by researchers, each of whom spent weeks, sometimes months, observing and conversing with teachers and students in schools. The field trial was, of course, at the other end of the research spectrum—paper and pencil instruments used on a single occasion in over 600 classrooms in a single province.

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[23] Background Study 52. Science Education in Canadian Schools: Vol. III. Case Studies of Science Teaching. Ottawa: Supply and Services Canada, Hull, Quebec, 1984.

[24] Fictitious names are used.

When we see congruence in the findings of the two studies, it strengthens our faith in their validity. It also means that we can use the richer Science Council report to help us understand the more indirect reports we have from Ontario teachers. An attempt will be made to draw the various threads together in the final chapter. We turn now to responses from students about the place and importance of experiments in the teaching and learning of Chemistry.

Experiments—The Students' View

We know already that these were a select group of able students with more than an average interest in science. From the teachers, we know that a considerable amount of time is spent in Chemistry classes on one or another aspect of experiments. Would the students like more, or less of this? What aspects do they find easy, which important? What do they like most? Do they prefer to work with other students or to work alone? Might they rather watch an expert demonstration than struggle with the chemicals and beakers and burners themselves? These were the questions put to students in the student questionnaire (Appendix B).

The findings were all strong and in one direction--students like experiments, and find them a good way to learn. They would rather work with other students than work alone or watch someone else do them. They find most difficult just what one would expect, the intellectual work of explaining results, generating theories, and designing experiments. In passing, we note that these are objectives given the least emphasis by teachers.

Responses to Attitude Items

Among the 56 attitude items discussed in Section 2, 20 referred explicitly to experiments. In this chapter, we are interested in just how much the students agreed (or disagreed) with the items, as opposed to the earlier interest in relationships among the items. Agreement was coded on a five-point scale:

1	2	3	4	5
Strongly disagree	Disagree	Undecided	Agree	Strongly agree

Student responses to the 20 items on experiments are summarized in Table 14, according to the strength of agreement or disagreement. The salient points have already been mentioned—preference for working with others, rather than watching, and a general perception that experiments are a good way to learn. Another aspect is the predictability of results. On this point, the students showed some ambivalence, agreeing strongly with I enjoy demonstrations or experiments which give unexpected results and I am interested in the unexpected results that sometime occur in chemistry experiments, but also moderately with I get annoyed when I don't get the expected results in chemistry.

What Students Like, Find Easy, and Regard as Important

Students were asked to give three ratings to each of 15 activities, 13 of which referred directly to experiments. Each rating was given by choice of a point on a five-point scale, one for dislike to like, one for hard to easy and a third for not important to important.

1	2	3	4	5
Dislike a lot	Dislike	Undecided	Like	Like a lot

1	3	4	5	5
Very hard	Hard	Undecided	Easy	Very easy

1	2	3	4	5
Hardly at all important	Undecided important	Important	Very	Very important

TABLE 14

How Students Feel About Chemistry Experiments.*

This table tells us:

Students enjoy doing experiments for themselves and feel experiments are a good way to learn

Statements with which students AGREE

Strongly	I would rather work with someone else than do experiments by myself. (4.0)
	I would rather do experiments myself than watch other students do them. (4.0)
	Chemistry experiments are fun. (3.9)
	I enjoy demonstrations or experiments which give unexpected results. (3.9)
	I am interested in the unexpected results that sometime occur in chemistry experiments. (3.9)
	I find that doing experiments helps me to understand chemistry. (3.9)
Moderately	I would like to spend more time doing experiments. (3.6)
	I like to try out new ideas by doing chemistry experiments. (3.6)
	Chemistry experiments can be frustrating. (3.5)
	I get annoyed when I don't get the expected results in chemistry. (3.3)

Statements about which students are UNDECIDED

	I would rather do experiments that involve measurements than experiments involving only qualitative observations. (2.9)
	It is important to know the expected result of an experiment before it is performed. (3.0)

Statements with which students DISAGREE

Strongly	The most difficult part of the chemistry course is learning to use laboratory equipment. (1.8)
	If you know what the result should be, there's no point in doing an experiment. (2.1)
	I would rather watch the teacher do experiments than do them myself. (2.1)
	Doing experiments is too slow a way to learn chemistry. (2.1
	Doing experiments did not help me learn chemistry. (2.1)
Moderately	I prefer to read why things happen rather than to do an experiment to find out. (2.3)
	It is better to be told scientific facts than to try to discover them from experiments. (2.3)
	Chemistry is dangerous. (2.4)

*Numbers in parentheses are average over all students of their responses on the five-point scale. Where 1 = strongly disagree and 5 = strongly agree

Because each activity was rated three times, the data can be summarized in a three-dimensional array, as in Figure 4. To read the figure, imagine a table top or other flat surface with a centre point representing indecision—completely undecided. Any activity associated with the centre point would be one about which students had no strong, or even mild, feelings. That point is marked by a small open circle whose diameter is more than enough to cover two standard deviations in the averages used to place the activities on the figure.[25] The numbered boxes mark the location of the activities, and the farther a box is from the centre circle, the stronger the feeling.

The easiest observation to make is that all of the activities were rated by the students as important to very important (they are all above the horizontal plane). It is not obvious in the figure, but close examination will reveal that the two most important (the highest two) are Explaining the results of experiments and Recording the observations of experiments. Of these two, the first was seen as more difficult than the second, since it is found on the left, hard side of the undecided line. To see this, follow the vertical line on which box 53 sits to the dot at its base on the horizontal plane. The dot is just this side of the division between dislike and like, on the like side. The feelings about activity 53 may thus be summarized as, "It is moderately difficult, we like it a little, and it is very important."

It probably comes as no surprise that students reported Cleaning up after experiments (box 39) as easy, the easiest of all these activities, and that they don't like to do it very much. Teachers may be encouraged that students see the activity as quite important. Two activities (37 and 41) tied for being most liked, Working with others on experiments and Handling scientific equipment. Both were rated as very easy, but Working with others was seen as only moderately important. Even the most difficult activity, Generating theories to test observations, was not seen as very difficult.

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[25] Responses were received from over 3000 students to each activity, and no important differences were observed between grades or other groupings of students. Each point was thus defined by the three arithmetic means of the ratings on the three five-point scales.

Figure 4: Three-dimensional representation of ratings by students of the easiness, liking and importance of 13 aspects of experiments in chemistry classes. Easiness and liking define the horizontal plane and importance the vertical dimension.

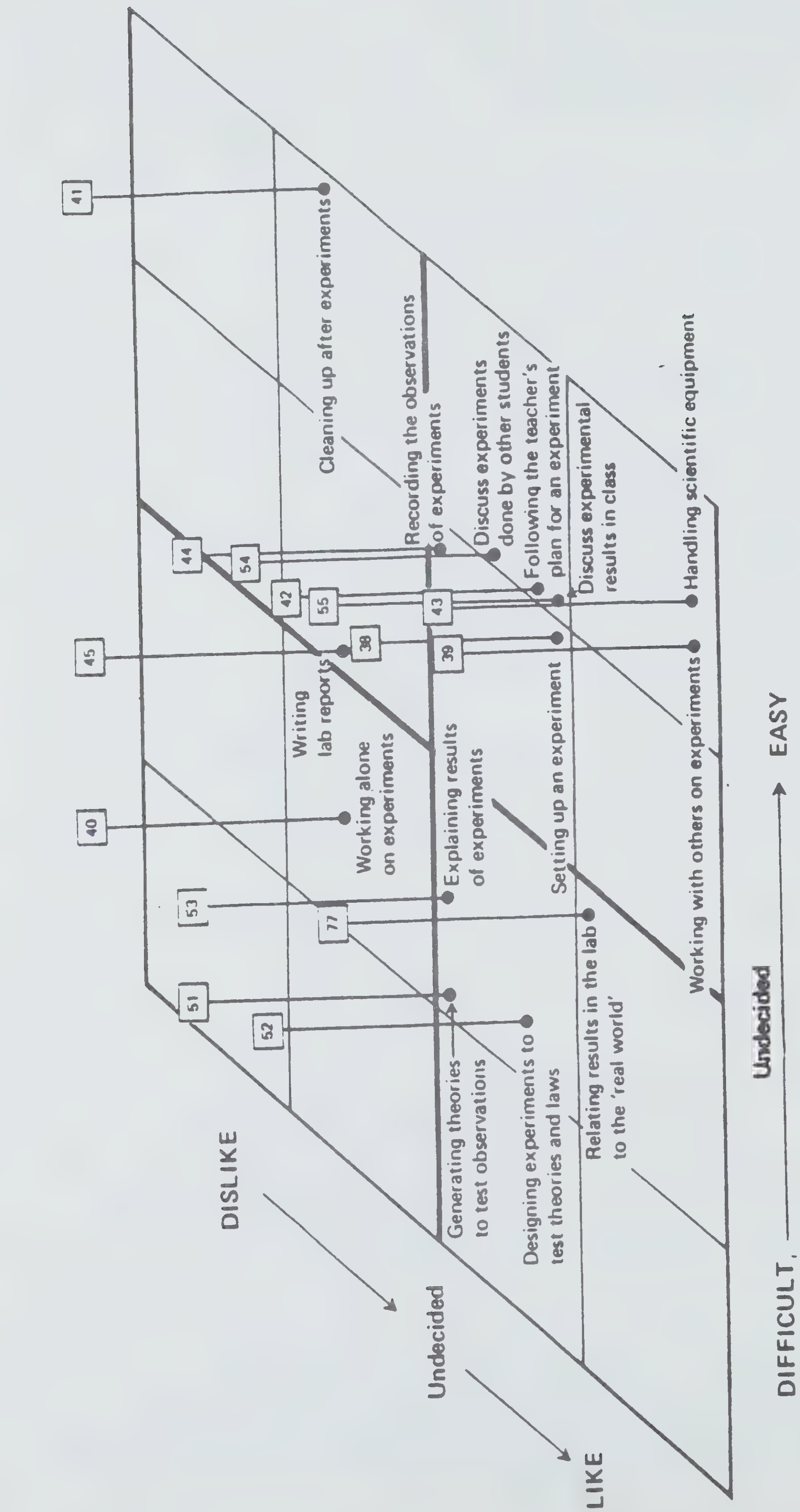

Figure 4-1: Three-dimensional representation of ratings by students of the easiness, liking and importance of 13 aspects of experiments in chemistry classes. Easiness and liking define the horizontal plane and importance the vertical dimension.

In general, these results confirm the general pattern, and support those who would give more emphasis to teaching Chemistry than to doing experiments. In the Science Council study, many teachers expressed the view that experiments were too time-consuming (unless rigidly controlled); and they felt under pressure to cover the content of the syllabus. Students disagree on all counts, as did the authors of the Science Council reports.

EXAMINATIONS AND HOMEWORK

There were no provincial examinations at the end of secondary school in Ontario in 1983. School boards tended to have very general policies, leaving decisions to the schools. This most often meant that decisions about type and timing of examinations were made at the individual school's departmental level. As would be expected, this has resulted in considerable diversity, with a few teachers reporting no examinations at all and many reporting both term and end-of-course examinations. The same comments apply to setting homework, except that this is even more varied in practice.

Examination Policies

Teachers were asked five questions about examinations:

- Does your school have a compulsory examination in Chemistry at the end of the course?
- Do your Chemistry students have Chemistry exams during the course?
- Do you allow your students to use calculators for exams?
- Are your Chemistry exams open book?
- Do you supply reference materials for use in your chemistry exams?

The answers to the questions about calculators and open-book examinations can be easily summarized—calculators yes, open-book examinations no. In both Grade 12 and Grade 13, 98 per cent of teachers permit students to use calculators on examinations, but only 2 or 3 per cent have open-book exams. The question about reference materials was not quite so one-sided—only three quarters of the teachers supply reference materials for use in Chemistry exams.

Compulsory end-of-course examinations were much more common in semester (76 per cent) than in full-year (28 per cent) courses. On the other hand, all teachers in full-year courses reported that their

students had Chemistry examinations during the course, against 58 per cent in semester classes. For some reason, perhaps the tighter time schedule, about half the teachers (or the school administrators) in semester schools put off examinations until the end of the course. Another factor is the number of students. Teachers in full-year classes may have as many as 180 students, and do not have time to mark final examinations for every student.

When we looked at performance on the OAIP instruments in those classes, however, there was no difference between semester and full-year classes. The two questions about examinations defined four categories of classes (no exams, during the course only, at the end of the course only, both during and at the end), and when we compared the classes according to these categories, differences were found—not only on achievement but also on opportunity to learn (OTL). (The OTL measure was explained on page 30.) There are surely other differences among those classes, therefore, so the examination policy is not likely to be the complete explanation for the differences in achievement. Students in classes with no examinations during the course reported doing more homework than those who had such exams, for example.

As shown in Table 15, Grade 12 classes that had examinations both during the course and at the end had higher average achievement and higher average OTL. In Grade 13, there was no difference in achievement, but OTL was again higher. Teachers in those 63 Grade 12 and 52 Grade 13 classes (often the same teacher in 12 and 13) managed to teach more (according to the perceptions of the students) and still give examinations both during and at the end of the course. To fully explore this finding, we would want to know whether the students in those classes were generally more able, but unfortunately we do not have that information.

The few classes in which no examinations are required at the end and none given during the year account for much of the difference in achievement means. When data from these classes were examined in more detail, no striking differences emerged. However, more of them were on a semester system (five out of seven) than the average (33 per cent),

TABLE 15

Examination Policy, Achivement, and Opportunity to Learn in Chemistry Classes

Examinations during the course?

Full-year	Semester
100%	58%

Compulsory examinations at the end of the course?

Full-year	Semester
28%	76%

Examinations and achievement

	Grade 12			Grade 13		
Policy	No. of Classes	Avg. Ach.**	OTL*	No. of Classes	Avg. Ach.	OTL*
During and End	63 (29%)	52	2.45	52 (36%)	54	2.41
End only	30 (14%)	49	2.41	17 (12%)	51	2.31
During only	121 (56%)	49	2.43	74 (51%)	53	2.38
No exams	4 (2%)	42	2.23	3 (2%)	53	2.28

Differences significant: *p<.05. **p<.01.

and three of the seven semester classes were in one school—two Grade 12s and one Grade 13. Following this lead, data from the three classes in that one school were extracted from the files to see what they would yield. This case study from a distance is presented in the next section. Looking at the details of actual classes helps remind us that there is no simple explanation for the outcomes of schooling.

Detailed Study of a Special Case

Chemistry 13 in Trillium High was taught by Mr. Veteran in 1983, just as it had been for the last few years.[26] As a Department Head who had been teaching for more than 25 years, he taught the Grade 13 class, although both of his colleagues had already been teaching Chemistry for 6 to 10 years (and all three had specialist certificates in Chemistry). They were comfortable with the school's semester system, and all followed the Head's lead in not giving examinations during the year nor requiring an examination at the end of the course.

Trillium High is a large school (over 1000 students in Grades 11, 12, and 13) located in a small to medium-sized town just beyond the suburbs of a city. The geographers call the area rural, but many of the parents work in the city, and some of the teachers live in the city. The school building is not more than 20 years old and has quite modern science laboratories.

The Teacher's View

The Head taught two sections of Chemistry last year and three other courses (everyone taught General Science) for a total of 285

[26] The names are fictitious, of course, since none of them are known. The predominance of males among Chemistry teachers, especially Department Heads, makes it reasonable to guess that the teacher was male. Since there was only one Grade 13 in the school, we will assume the Department Head usually teaches it. The teacher's age group, number of years' experience, and other characteristics are all taken from the teacher questionnaire. Information about the students was taken from the student questionnaire. The region of the province and the type of community the school was located in was available from the sampling plan, but the names of the board and school, and the identity of the class were not.

minutes per week. It was a full but not overly heavy load, as would be expected of the Head. The Grade 13 class was reasonably large, with 27 students,[27] but he knew how to handle it. It made the labs somewhat unwieldy, and he decided to omit several topics that were sometimes taught for a few periods (Electron Arrangement and the Periodic Table, Molecules in the Gas Phase, Bonding in Solids and Liquids, and The 6th and 7th row elements).

He gave special emphasis to Oxidation-Reduction Reactions, devoting about 20 periods to the topic. (Periods were 57 minutes long.) This was more time than average, but he liked teaching the topic, and believed it to be important. About 10 periods were spent on each of the other topics, except Solubility Equilibria (which got only 5). They covered Solubility Equilibria pretty well in the Grade 12 course at Trillium.

Mr. Veteran was not too pleased with the class this year. He was interested to see that half the class were actually Grade 12 students. They didn't lack ability, they were reasonably well behaved, and, having got this far, were reasonably well prepared. Unlike science classes in general, this class had more girls than boys (by a little—15 to 12), but, other than that, the class was a typical one. The biggest problem, in his opinion, was that they didn't do their homework. Their motivation was a problem, to some extent, and they didn't want to accept responsibility. If he were to complain about these things in the staff room, however, the response would likely be, "So what else is new?"

When results of a provincial survey came out, the Head saw that he had reason to be concerned.[28] The class hadn't done badly, in general, (48 per cent, as against the provincial mean of 53), but there were some real soft spots he had not anticipated. Moreover, his colleagues'

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[27] 15 per cent of Grade 13 classes in the sample had more than 25 students.

[28] The Department Head's thoughts are, of course, an invention, but the results are not. This is the author's description of what might happen if results were fed back to teachers in a timely fashion.

Grade 12 classes had fared even worse, scoring under 40 per cent when the provincial average in Grade 12 had been 50 per cent. They all decided to take a close look at the results.

Mr. Veteran's emphasis on Oxidation-Reduction was effective. The students answered 63 per cent of the items correctly, against only 50 per cent in the province as a whole. They also bettered the provincial average on Bonding in Solids and Liquids and the Chemistry of Carbon Compounds, but he couldn't take credit for the good performance on the former, because he hadn't taught that topic this year! "What a good job we did in Grade 12!" he said to his colleagues.

The real disappointment was Equilibrium in Chemical Reactions. The students had done no better than if they had guessed (27 per cent), and yet he had spent 10 periods on it. Performance was also low on Energy Effect and Aqueous Acids and Bases, and these had also been allocated 10 periods. Clearly, the message was not getting across as well as he had thought. Other teachers managed to cover more material and still get better results. "Do they have as many Grade 12s in their classes? Are the students better motivated? I wonder what the students said on their questionnaire?"[29]

The Students of Chemistry 13, Trillium, 1982-83

The class was typical in most ways--typical, that is, for Grade 13 Chemistry classes. Of the 27 students, 22 were planning to go to university and 2 to a college of applied arts and technology. Only one was going out to look for a full-time job after this year. Reflecting the community, 24 of the students' families spoke only English at home. The other three students usually spoke English at home, but their families spoke another language. Two of these students were planning to go to university. Had they compared notes, students would have found that everyone had a part-time job, whereas the provincial average was more like 60 per cent. Half the students in the class worked both

[29]Very few teachers had as large a percentage of Grade 12 students as did Mr. Veteran. In fact, 82 per cent reported that a quarter or less of their students were Grade 12s.

after school and on weekends. Mr. Veteran's perception that students didn't do their homework was only partly correct. He recalled assigning about four hours of homework per week, and 60 per cent of the students said they did three or more hours per week. A quarter of them said they did four or more hours per week. Only two students said that too much homework was assigned—both boys who were not going on to post-secondary study. According to their own reports, at least, the students work hard on their lessons, in spite of their part-time jobs. Two-thirds of them said they did between 7 and 11 hours of homework per week, in total.

About 40 per cent of the students said yes to the statement I intend to pursue a science-related career after leaving high school, but over half said, I don't know. One-third also did not know whether the Chemistry course was required for their post-secondary plans. This could be taken as a sign of ambivalence and mixed motivation about studying Chemistry, something that would support Mr. Veteran's perception that they were not strongly motivated. Clearly, some were keen science students, but these made up less than half of the class.

Their responses to the attitude items (see Chapter 2) were a mirror of the province. They liked experiments and would like to do more of them. Chemistry is important for their future, they said, and important for the country. Overall, the girls were more positive than the boys, except that boys liked to visit science museums more, and boys disagreed more with the statement that man-made chemicals do more harm than good. The girls thought that working with others on experiments was more important than the boys did, and, more than the boys, they liked recording the observations of experiments.

Reflections on the Case Study

Recall that this class came to the author's attention because the teachers reported no examinations either during or at the end of the year. The average number of OAIP instruments answered correctly was lower than in the province as a whole, and these two characteristics suggested the need for a closer look, in an effort at better

understanding. Saying that there were no examinations still leaves room for unit and chapter tests, since in Ontario the word "examination" is usually reserved for major, formal tests.

The school is clearly not in the inner city, nor is it in an area of economic hardship. Mr. Veteran and his colleagues can look with profit to their teaching, if they see reason to be concerned about achievement. As comprehensive as the Chemistry OAIP is, this Field Trial was able to touch only part of the course, and the results reported here were taken only from the multiple-choice instruments. Students who do not face examinations in class might be even less well motivated than those in other schools to try hard when the results do not affect their marks.

The Head and the teachers may well have other evidence that satisfies them that the overall performance of the students is quite acceptable. If they want student performance to improve on the type of assessment instruments included in the field trial, then they have a method ready at hand: one or two examinations per year counting significantly toward a student's final mark would very likely result in improved performance on examination-like tasks. On the other hand, the results of the Field Trial might well lead Mr. Veteran and his colleagues to shift their emphasis amongst topics and to try other ways of presenting material now given considerable time, with few achievement results to show for it.

Homework

After a time of relative neglect by researchers, homework has begun to receive attention again. In reviewing five years of work in Mathematics assessment in England, Wales, and Northern Ireland, Derek Foxman found consistent regional differences that he suggested could all be explained by the amount of time spent on homework.[30] The

[30] A popular summary of the report was published in the Times Educational Supplement of December 10, 1982, p. 19. Homework was mentioned, as well, on p. 3.

surveys done by the Assessment of Performance Unit (APU) found that, "in Northern Ireland, 90 per cent of primary school children are given at least an hour's mathematics homework every week. This is much more than England (30 per cent) and Wales (50 per cent)."

In a report to the British Commons Select Committee on education, Dr. Clare Burstall, the director of the National Foundation for Educational Research, said there were increasing signs that where children were set homework, were encouraged by parents to do it and had it regularly marked at school, there was "a steady consistent association between that and the level of performance".[31] Mr. Foxman called for caution, however, noting that teachers might have created an association by giving More homework to high attainers. "In spite of our results we do not know to what extent homework actively raises attainment."

A huge study in the USA (20,000 students in their last year of secondary school) concluded that homework can enable less able students to perform up to the level of their more able classmates.[32] Teachers, however, tended to ask less of the less able students, widening the gap rather than narrowing it. The US study was not enthusiastic about homework for elementary school children, but deplored the small amounts done at the secondary level. American teenagers do about four hours of homework per week, just a little more time than they spend on television every night. Thirteen per cent do no homework at all, and only 6 per cent study for as much as 10 hours per week. With this as background, we turn to results from the field trial surveys.

[31] This and the following comment by Foxman were cited in the Times Educational Supplement, May 10, 1985.

[32] A researcher at Harvard, Ms Helen Featherstone, pulled together results from a dozen separate studies in arriving at her conclusions.

Amount of Homework Assigned and Amount Done

We might not expect to find the same results in Ontario Grade 12 and 13 Chemistry classes as in the average American high school class, and we do not. Three-quarters of Grade 12 teachers assign from one to three hours of homework per week and, with few exceptions, the rest assign four hours. Grade 13 teachers assign more, about one hour more per week on average. As we have found consistently, however, there is considerable diversity. In Grade 13, the midrange among teachers (those with no administrative responsibility) was all the way from two to five hours per week.[33] The amount of homework assigned was not related to teacher characteristics such as age and number of years of experience.

The average number of hours reported by students was about two hours per week in Grade 12 and slightly more in Grade 13, but this figure is misleading, in that girls report more than boys, those going on to university more than those not going on, students who speak other than English at home more than others, and those planning a science career more than those who are not, or who are undecided. A plausible inference is that those students who have a special interest in doing well in school (a rather large proportion in these classes) do the homework that teachers assign.

Students were asked whether they felt they were assigned too much homework, about the right amount, or not enough. Over 80 per cent of them said that the amount of homework was about the right amount. Fewer than 10 per cent of those bound for university said that there was too much homework, but 15 per cent of the others thought so. Since such a high proportion are university bound (about 70 per cent), the matter of homework does not seem to be a big problem. For interest's sake, we can compare the statistics on total homework with those quoted in the American study.

[33] Recall that the midrange covers the middle 50 per cent of the teachers--a quarter assign less than two hours, and a quarter assign more than five hours of homework per week.

Ontario students were presented with a six-point scale when asked how much homework they did. The scales for Chemistry and summaries of the student responses are presented in Table 16. A parallel table for homework in all subjects is presented in Table 17. From Table 17 we can see that only 2 per cent do no homework at all (vs. 13 per cent in the general U.S. sample), and 27 per cent do 11 or more hours per week (compared with 6 per cent in the U.S. who do 10 hours or more).

TABLE 16

Amount of Chemistry Homework Students Do.
Summary of Responses to the Question:

Approximately how many hours of chemistry homework have you been doing each week outside of class?

	Grade 12		Grade 13	
	N	%	N	%
None at all	218	6	98	5
Less than 1 hour	1008	26	395	20
1-2 hours per week	1396	36	671	34
2-3 hours per week	861	22	559	28
3-4 hours per week	409	10	266	13
More than 4 hours	0	0	0	0
	3892	100	1989	100

The U.S. study remarked that many teenagers work long hours in paid employment instead of studying, and that teachers therefore do not ask for homework to be done. Ontario students often work, as well, and, when they do, they do less homework. The difference is not great, however, amounting to about one hour per week (all figures being student reports). The difference in the amount of homework done is greater between those going on to university and those not going on, than between those who work and those who do not. Moreover, it doesn't matter whether students work just after school or on the weekend, or whether they work at both times. The university-bound students do more homework either way (and about the same proportion of them work).

When one looks at the time spent on homework, a plausible explanation appears for its importance. It was noted in a previous chapter that a secondary school credit course must have 110 hours of

classroom instruction. That works out to just over three hours per week (depending on how many weeks of school one takes). Thus, students who did more than three hours of well-directed homework per week would double their Chemistry study time. Since focused learning time is the single most powerful influence on achievement,[34] we see that 75 to 80 per cent of students add significantly to their learning time via homework.

TABLE 17

Total Amount of Homework Students Do in All Subjects.
Summary of Responses to the Question:

Approximately how many hours of homework do you usually each week, including weekends, for all subjects (total)?

	Grade 12		Grade 13	
	N	%	N	%
None at all	106	3	37	2
Less than 3 hours per week	712	17	281	13
3-7 hours per week	1421	34	577	26
7-11 hours per week	989	24	556	25
11-14 hours per week	575	14	432	19
More than 14 hours per week	347	8	359	15
	4150	100	2242	100

Homework and Achievement

It may come as a disappointment, but not a surprise, that no simple link was found in the Field Trial between achievement and the amount of homework done. Because of the item sampling design, no analysis was possible at the student level, so the variables used were the amount of homework assigned by the teacher and the average achievement in the class. As we saw above, the amount of homework assigned varied over quite a range. Analyses of the achievement data revealed a tiny advantage for classes in which more homework was assigned (about one percentage point in achievement). The difference associated with the examination policy was larger (two to three percentage points). Neither of these differences appears great enough to yield policy recommendations.

[34] For references, see Les McLean, The Craft of Student Evaluation in Canada. Toronto: Canadian Education Association, 1985.

SYNTHESIS AND OVERVIEW

> Chemistry retains a historic role as a crossroads of the sciences and a tremendous source of practical applications, but new capabilities and new tools have been added.
>
> --Philip H. Abelson, 1985.

The "crossroads of the sciences" is an increasingly apt description, as chemists utilize theories and techniques from physics, mathematics, and biology to expand our insights into the substances that surround us. Chemistry is a popular subject in Ontario secondary schools, judging from the number of students revealed by our survey. The sample of schools included just about half of those with Advanced-level classes, implying that over 25,000 students are following these academic courses. Since over half of these were planning to follow a science-related career, they represent a substantial cohort of young people who leave high school with advanced preparation in science.

When the Field Trial of the Chemistry OAIP was designed, the OISE team and the Advisory Committee did not know that the Science Council study was under way. The comprehensive analysis in the various reports from that national study provides a compelling backdrop for the findings of this provincial survey at the senior secondary level, however, and it will be used to structure this synthesis. The headings of the sections below are taken from the principal recommendations of the Science Council report.

Nurturing Human Resources

For the next decade, there will be little mobility in the teaching force. Professional development opportunities for teachers will thus be an important consideration. The field trial survey found that at least half the teachers regarded their opportunities as inadequate, and that in some boards of education the proportion was more like two-thirds. The Science Council researchers wrote that, "for two-thirds of all science teachers, in-service education programs are either

nonexistent or ineffective." Twelve recommendations were made, amongst them, that teachers should develop a three-year professional development plan (reviewed annually), that there should be at least five days during the regular school year for professional development, and the like.[35]

Ontario teachers favoured one-day workshops on a topic, so this would be quite in keeping with the recommendation for professional development days during the school year. The Science Council report recommended a minimum of 15 days annually, which would require more systematic planning for the out-of-school time. Incentives would likely be important, considering that 15 per cent of Ontario teachers reported no systematic updating.

Encouraging the Participation of Young Women

The Science Council's concern with low participation of girls in physical science courses received only weak support in the Field Trial survey. True, there were fewer young women in these senior secondary courses than there were young men, but the difference was small (46 per cent women in Grade 12, 43 per cent in Grade 13). For some reason, Chemistry may be more attractive, since the same survey found 41 per cent women in Grade 11 Advanced-level Physics and only 28 per cent in Grade 13 Physics. Only 21 per cent of the students in the Grade 11 General-level Physics courses were women.

There is clearly reason to support the Science Council's call for changes in curriculum (a science-technology-society emphasis, with appropriate attention to women in science), teaching methods (ensuring that all students manipulate equipment and take measurements, for example) and career counselling (with better information and more female role models). There is something in Chemistry courses that encourages young women, however, because they enrol in them in larger numbers than in Mathematics or Physics. A plausible explanation is the Chemistry prerequisite for many health-related careers.[36]

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[35] Report 36, pp. 53-58.

[36] This explanation was suggested by a member of the Advisory Committee.

Challenging High Achievers and Science Enthusiasts

As the picture sketched in Chapter 2 showed, the students who participated in the Field Trial survey were science enthusiasts, and they certainly included some high achievers. Responses to the items on attitude in the student questionnaire suggest enthusiasm. They strongly agreed with I really want to do well in Chemistry and disagreed with Chemistry is harder for me than it is for most other people. Results on the open-ended achievement instruments (not reported here) revealed a few students performing at a very high level indeed.

Ontario's Advanced-level courses are intended to meet the Science Council's recommendation for "program provisions made to encourage and challenge them to further inquiry." The present survey does not tell us how successful the courses are in challenging the students to further inquiry, but it would appear from the achievement results that the courses are academically challenging. That more might be done is suggested by the responses to the items on experiments. Students feel that experiments are a good way to learn, and they would like to spend more time doing experiments. Perhaps they have been challenged to further inquiry, after all.

Presenting a More Authentic View of Science

Based on a review of textbooks, a study of curriculum guides, and observation in classrooms, the Science Council researchers concluded that "textbook science tends to be overly standardized and simplified in order to present a smooth road to scientific knowledge." They recommend that "the view of science and technology presented to students should include historical, social, and philosophical dimensions." The last-mentioned might be included in the portrait by offering students "a reflection on the nature of scientific knowledge."[37]

Judging from the list of topics and from teacher comments, the Ontario courses are quite far from presenting the more authentic view recommended by the Science Council. Among the activities listed on the teacher questionnaire, for example, was Discussing scientific issues and values. Three-quarters of the teachers reported that the students spent less than 5 per cent of the time on such discussions, and many spent no time at all. The Science Council researchers commented in several places that teachers felt very pressed by the need to cover the syllabus; that is, to present the scientific content. As quoted in Section 3, one Chemistry teacher wrote in: "The rigorous demands of the curriculum content permit little time for discussion of scientific issues and values, although that would be a welcome addition to the curriculum."

Apart from the teacher question cited above, the Field Trial survey hardly touched the questions of technology, science, and society. That these were not uppermost in teachers' and researchers' minds suggests that there is indeed a selling job to do if they are to be given the emphasis the Science Council team would recommend. The one area that was touched on in the student survey was the certainty

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[37] Report 36, p. 37.

one may attach to the experimental process. The Science Council team deplored any view of science as regular and predictable, "overly standardized and simplified." These advanced students in Ontario at least showed some healthy respect for a search for answers not known in advance.

They disagreed, for example, with If you know what the result should be, there's no point in doing an experiment and agreed with I enjoy demonstrations or experiments which give unexpected results. Chemistry did not appear overly simple to them, since a majority disagreed with I find Chemistry the easiest of the sciences. Their Chemistry course must have been related somewhat to society, since they strongly agreed with Chemistry has improved our standard of living and Money spent on applying results in science is money well spent.

Emphasizing the Science-Technology-Society Connection

Considerable space was devoted in the Science Council report to the discussions leading up to the recommendation that

> Science should be taught at all levels of school, with an emphasis and focus on the relationships of science, technology, and society, in order to increase the scientific literacy of all citizens.

The research team went on to comment, "Objectives of this type appear in the curriculum guides of all ministries of education but, for the most part, little importance is given to them by teachers, textbook authors, and other science educators." They recommended that, in the senior years, such objectives might occupy 25 per cent of the course.[38] There is certainly little in the Field Trial data to suggest that such objectives are given more than passing mention, and it seems most unlikely that the time given to them even begins to approach 25 per cent. The achievement instruments in the Chemistry OAIP do not touch such objectives at all.

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[38] Report 36, pp. 38-39.

The Science Council report also recommends, "Technology education should form a greater proportion of secondary school education for all students," commenting that "courses of this nature will be new to Canadian schools, but we can build on the experience of others."[39] The recent curriculum reform, Ontario Schools, Intermediate and Secondary (OSIS), introduced the requirement of one course in technology for secondary school graduation, giving explicit support to this recommendation; and the new Chemistry curriculum guideline gives emphasis to societal applications as mandatory content in each unit.

Setting Science Education in a Canadian Context

The universality of science may be taken to an extreme in senior courses, and the Field Trial was no exception. The word Canada (or variations, Canadian ...) does not appear at all in the teacher questionnaire, and only appears once in the student questionnaire (in a demographic sense, rather than having to do with attitudes or with science generally). The achievement instruments in the Chemistry OAIP are cleansed of any references to countries. As with the science technology-society links, provision of a Canadian context seems to be left to local initiative, with no reinforcement in the assessment provisions.

Ensuring Quality in Science Education

The whole Science Council study might be regarded as a compendium of ways to ensure high quality science education, but the team chose to put their recommendation about assessment of student learning under the heading of ensuring quality. They stressed that "assessment techniques must be developed and implemented for all the objectives of science education, to inform individual students about their progress and to

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39 Report 36, pp. 42-43.

monitor the effectiveness of provincial science education systems" (emphasis in original).[40] The language is quite similar to that used to describe the OAIP:

> The Ontario Assessment Instrument Pool (OAIP)/La Banque d'instruments de mesure de l'Ontario (BIMO) is a resource designed to assist those in education in fulfilling their responsibilities for evaluating student achievement and the effectiveness of school programs.[41]

The Science Council report made note of the OAIP, with a reservation, as follows: "Ontario has policies in place for a 'pool' of items for teachers to use for student asessment (although, regrettably, most of the science items to date are content measures only)."[42] Since that statement was written, other categories have been added, namely, "Laboratory," "Essay," and "Storyline" instruments. Content measures certainly dominate, but some recognition has been given to the need for measures of other types of objectives. Not all content categories are well covered, but those topics given most attention by teachers are also the ones with the most assessment instruments.

All this said, it must still be acknowledged that the vast majority of the instruments are of the multiple-choice type, and that much remains to be done if the final words of the Science Council team are to be heeded:

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[40] Report 36, p. 43.

[41] Les McLean, Report of the Field Trials in English and Mathematics, Intermediate Division. Toronto: Ontario Ministry of Education, 1982, p. 219.

[42] Report 36, p. 44.

> Of particular importance must be assessment instruments designed to measure progress towards such aims as creativity, problem-solving skills and understanding about science, technology, and society. Progress in this assessment area is vital if the worthwhile aims of science education are to be taken seriously.[43]

OAIP Achievements

It would be inappropriate to end a report on an OAIP Field Trial with observations by the Science Council, interesting and relevant though they be. With thousands of instruments keyed to the curriculum, the Chemistry OAIP is a major resource for use in improving the teaching and learning of senior Chemistry.

Results from the Field Trial can also contribute to the improvement of teaching and learning, as this report has attempted to show. The report by Talesnick and McLean referred to earlier[44] contains literally hundreds of practical suggestions, all of them based on analysis of student responses to the achievement instruments. The implications for instruction in the item, topic, and classroom-level scores from the Field Trial were analyzed and compared, and the conclusion reached that "virtually all of the pedagogically relevant information in test responses is to be found in the item (instrument) level."[45]

Examination of the comments made by Professor Irwin Talesnick about student performance on the 500 Grade 12 multiple-choice Chemistry

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[43] Report 36, p. 44.

[44] See Note 1

[45] Les McLean, Drawing Implications for Instruction from Item, Topic and Classroom-level Scores in Large-scale Science Assessment. Paper presented at the annual meeting of the American Educational Research Association, Chicago, April 2, 1985, p. 11.

instruments revealed groups of instruments from which implications were drawn for both general and specific pedagogical points (content and technique), evaluation, problems with prerequisites, and with symbols and language.[46]

In the previous chapter, an example was given to show how information from teacher and student answers, and derived from student performance on the achievement instruments, can be used to produce a thought-provoking picture of teaching and learning in a single classroom. The example reinforces still further the inference that large-scale assessment is best observed as relevant to instruction if the results are analyzed in detail rather than just summarized in provincial means-and-standard deviations.

Finally, the development of the OAIP, including field trials, has had the effect of sensitizing many teachers to the possibility of systematic, curriculum-based measurement. It has done this by example and by making available to teachers the tools they need to do the job for themselves, not in isolation but in the context of the province as a whole. A major goal of this report has been to assist with this sensitization. Comments are invited from science educators at all levels.

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[46] Ibid., p. 12.

APPENDIX A

CHEMISTRY TEACHER QUESTIONNAIRE

SURVEY OF ONTARIO CHEMISTRY TEACHERS
IN THE SENIOR DIVISION, 1983

SURVEY OF ONTARIO CHEMISTRY TEACHERS

IN THE SENIOR DIVISION 1983

We are using the occasion of the OAIP Field Trials to conduct a survey of chemistry teachers and students in the senior division. This teacher questionnaire asks about your classes, the way you use your time, and the resources you have. Just as Statistics Canada does, we ensure that your responses will be entirely confidential.

The results of this survey will be published in the form of a report on the Field Trials and will be distributed to all Boards and secondary schools. It should be of interest to teachers, consultants, textbook authors and guideline writers. Cooperation by all teachers associated with the Field Trials will ensure a response from a representative sample of Ontario chemistry teachers. Please take some time to contribute your views to the survey and thus make it a truly representative one.

Thank you. The OISE research team.

Les McLean
Vince Gaudino
Mary Rosser

INSTRUCTIONS

In the questionnaire that follows you are asked to respond to a number of questions. Some questions ask you to circle your response(s), others ask you to fill in the appropriate information. Most of the questions ask you to respond for each grade and/or level you teach. Please answer each question as completely as possible.

A teacher questionnaire is included in each classroom package of materials. If you have more than one chemistry class participating in the Field Trials you will receive more than one questionnaire. Please complete ONLY ONE questionnaire. On the other questionnaires you receive, simply mark in the space below that you have already completed questionnaire number ___. Return each questionnaire along with the student answer sheets to your school OAIP coordinator.

Thank you for your cooperation.

I have already completed questionnaire number ______________

Questionnaire No. 3569

SECTION I

Please respond by circling the appropriate number(s).

A. What subject(s) do you teach? (Circle all that apply).
   1 Physics
   2 Chemistry
   3 Biology
   4 Mathematics
   5 General science (9-10)
   6 Other science(s)
   7 Other subject(s) (not science or math)

B. What is currently your strongest area of expertise?
   1 Chemistry
   2 Biology
   3 Physics
   4 Mathematics
   5 General science
   6 Other science(s)
   7 Other subject(s) (not math or science)

C. What level of responsibility do you have in the Science department?
   1 teacher
   2 assistant head of department
   3 head of department

D. Do you have a specialist certificate?
   1 yes
   2 no

E. If yes, in what subject(s) is your specialist certificate
   1 Chemistry only
   2 Physics only
   3 Biology only
   4 Mathematics only
   5 Science only
   6 Chemistry and Mathematics
   7 Chemistry and Physics
   8 Chemistry and Biology
   9 Physics and Mathematics
   10 Physics and Biology
   11 Mathematics and Biology
   12 Other

F. How many years have you been teaching (including this year)?
   1 1 year
   2 2 - 5 years
   3 6 - 10 years
   4 11 - 15 years
   5 16 - 25 years
   6 25+ years

G. How many years have you been teaching chemistry?
   1 1 year
   2 2 - 5 years
   3 6 - 10 years
   4 11 - 15 years
   5 16 - 25 years
   6 25+ years

H. I will be eligible for retirement (by age or number of years experience + age):
1 this school year
2 next school year
3 in 2 years
4 in 3 years
5 in 4-5 years
6 in 6-10 years
7 in 10+ years

I. What is your age group?
1 20-30
2 31-40
3 41-50
4 51-55
5 56-60
6 61-65
7 65+

J. Do you have... (Circle appropriate response(s))
1 a post graduate degree - science?
2 a post graduate degree - education?
3 industrial experience?
4 none of the above

K. Indicate the methods that you use to keep your knowledge of chemistry up-to-date.
1 extension courses at the university
2 workshops/seminars in your field
3 visits to industrial settings
4 reading new material in your field
5 no systematic updating
6 other

L. Are the professional development activities available to you adequate?
1 yes
2 no

M. What local activities would be most useful to you for updating your chemistry?
1 1/2 day workshops on a topic
2 1-day workshops on a topic
3 2-day workshops on a topic
4 university courses
5 industrial visits
6 reading
7 one week summer course
8 night courses

SECTION II

	12 Adv.	Grade 13
A. On the average what is your total instructional time per class per week (in minutes)?	______	______
B. How long are the periods (in minutes)?	______	______
C. How many sections of chemistry do you teach per year?	______	______
D. How many hours of homework per week do you normally assign your chemistry students?	______	______

E. Approximately what percentage of your grade 13 chemistry students are registered in grade 12? ______

		12 Adv.	Grade 13
F.	Are your chemistry courses semestered?	yes no	yes no
G.	Are double periods timetabled for your chemistry courses?	yes no	yes no
H.	Does your school have a compulsory examination in chemistry at the end of the course?	yes no	yes no
I.	Do your chemistry students have chemistry exams during the course?	yes no	yes no
J.	Is a computer available for use by your chemistry classes?	yes no	yes no
K.	Do you allow your students to use calculators for classwork?	yes no	yes no
L.	Do you allow your students to use calculators for exams?	yes no	yes no
M.	Are your chemistry exams open book?	yes no	yes no
N.	Do you supply reference materials for use in your chemistry exams?	yes no	yes no

O. Which of the following subjects do you think a student should take prior to or along with your course?

		12 Adv.	Grade 13
1	grade 9/10 physical sciences	1	1
2	grade 9/10 biological sciences	2	2
3	grade 9 mathematics	3	3
4	grade 10 mathematics	4	4
5	grade 11 mathematics	5	5
6	grade 11 physics	6	6
7	grade 12 chemistry	7	7
8	grade 12 mathematics	8	8
9	grade 13 algebra	9	9
10	grade 13 relations & functions (analysis)	10	10
11	grade 13 calculus	11	11
12	grade 13 physics	12	12
13	grade 13 biology	13	13
14	other science	14	14
15	other (specify) ______________		

III. Please indicate the approximate number of hours your chemistry classes spend on the following topics. (Enter zero if you don't cover the area in that grade. Use approximate hours to nearest whole number.)

	12 Adv.	Grade 13
Structure of Atoms	______	______
Structure of Aggregate Atoms	______	______
States of Matter and Gas Laws	______	______
Oxygen and Hydrogen	______	______
The Mole, Atomic Weight, Molecular Weights	______	______
Formulas, Nomenclature and Equations	______	______
Water and Solutions	______	______
Ions in Aqueous Solution	______	______
Elements of Group 2	______	______
Elements of Group 7	______	______
Periodic Classification of Elements	______	______
Energy Effects of Chemical Reactions	______	______
Rates of Chemical Reactions	______	______
Equilibrium in Chemical Reactions	______	______
Solubility Equilibria	______	______
Aqueous Acids and Bases	______	______
Oxidation - Reduction Reactions	______	______
Experimental Base for Atomic Theory	______	______
Electron Arrangement and the Periodic Table	______	______
Molecules in the Gas Phase	______	______
Bonding in Solids and Liquids	______	______
Chemistry of Carbon Compounds	______	______
3rd Row of the Periodic Table	______	______
4th Row Transition Elements	______	______
Some 6th and 7th Row Elements	______	______

IV. How adequate is each of the following in your school for the purpose of teaching science?

Response Code:
1 not required
2 needed but not available
3 inadequate
4 adequate
5 better than adequate

1	Storage space for science materials/equipment	1	2	3	4	5
2	Storage space for microscope slides	1	2	3	4	5
3	Storage space for volatiles	1	2	3	4	5
4	Storage space for student projects	1	2	3	4	5
5	Science preparation room	1	2	3	4	5
6	Water outlets	1	2	3	4	5
7	Electric outlets	1	2	3	4	5
8	Gas outlets	1	2	3	4	5
9	Sinks or drainage facilities	1	2	3	4	5
10	Amount of work space per student	1	2	3	4	5
11	Audio-visual equipment	1	2	3	4	5
12	Fume hood/closet	1	2	3	4	5
13	Ventilation	1	2	3	4	5
14	Chalkboard space	1	2	3	4	5
15	Bulletin board space	1	2	3	4	5

V. What safety equipment do you have in your science teaching area/room/laboratory? (Circle all that apply)

1 I have no safety equipment
2 Fire blankets
3 Fire extinguisher
4 Master gas shut-off
5 Approved first aid kit
6 Safety goggles
7 Asbestos gloves
8 Sand buckets and scoops
9 Eye-wash stations
10 Acid spill clean-up kits
11 Safety charts
12 Demonstration safety shields
13 Other (specify)______________________________

VI. How often do you use the following materials in your chemistry classes? (Circle the number which best describes your usage.)

Response Code:
1 frequently
2 often
3 occasionally
4 rarely
5 not at all

	12 Adv.	Grade 13
A. Student textbook.	1 2 3 4 5	1 2 3 4 5
B. Reference text books	1 2 3 4 5	1 2 3 4 5
C. Workbooks, worksheets, lab workbooks.	1 2 3 4 5	1 2 3 4 5
D. Locally produced teaching materials (board or school).	1 2 3 4 5	1 2 3 4 5

	12 Adv.	Grade 13
E. Personally produced teaching materials (unique to self or team of teachers).	1 2 3 4 5	1 2 3 4 5
F. Individualized materials.	1 2 3 4 5	1 2 3 4 5
G. Computer software.	1 2 3 4 5	1 2 3 4 5
H. Videotapes, audiotapes.	1 2 3 4 5	1 2 3 4 5
I. Laboratory exercises.	1 2 3 4 5	1 2 3 4 5
J. Personally produced lab exercises.	1 2 3 4 5	1 2 3 4 5
K. Films, film loops.	1 2 3 4 5	1 2 3 4 5
L. Supplementary problem exercises as drill.	1 2 3 4 5	1 2 3 4 5
M. Supplementary problem exercises for enrichment.	1 2 3 4 5	1 2 3 4 5

VII. To what extent do the factors below contribute to <u>poor</u> achievement in chemistry?

Response Code (Circle the appropriate number to the right of each statement.)

1 = not at all
2 = to a small extent
3 = to some extent
4 = to a significant extent
5 = to a great extent

	12 Adv.	Grade 13
A. Too many students per class.	1 2 3 4 5	1 2 3 4 5
B. Insufficient teaching materials.	1 2 3 4 5	1 2 3 4 5
C. Inadequate demonstration materials.	1 2 3 4 5	1 2 3 4 5
D. Inappropriate teaching materials.	1 2 3 4 5	1 2 3 4 5
E. Out-of-date equipment or facilities.	1 2 3 4 5	1 2 3 4 5
F. Too many students whose first language is not English.	1 2 3 4 5	1 2 3 4 5
G. Generally low student motivation.	1 2 3 4 5	1 2 3 4 5
H. Students not properly prepared for taking chemistry.	1 2 3 4 5	1 2 3 4 5
I. Students did not find the course was what they had expected.	1 2 3 4 5	1 2 3 4 5
J. Student failure to accept responsibility.	1 2 3 4 5	1 2 3 4 5

	12 Adv.	Grade 13
K. Student failure to do homework.	1 2 3 4 5	1 2 3 4 5
L. Student lack of ability.	1 2 3 4 5	1 2 3 4 5
M. Student misbehavior.	1 2 3 4 5	1 2 3 4 5
N. Student absenteeism.	1 2 3 4 5	1 2 3 4 5
O. Insufficient time to deal with individual student difficulties.	1 2 3 4 5	1 2 3 4 5
P. Chemistry content is too difficult.	1 2 3 4 5	1 2 3 4 5
Q. Too many chemistry topics to cover adequately in school year.	1 2 3 4 5	1 2 3 4 5

VIII. To what extent do you emphasize the following objectives in your chemistry classes?

Response Code (Please circle the appropriate number beside each statement.)

1 = not at all
2 = to a small extent
3 = to some extent
4 = to a significant extent
5 = to a great extent

	12 Adv.	Grade 13
A. Developing questionning skills	1 2 3 4 5	1 2 3 4 5
B. Learning science concepts.	1 2 3 4 5	1 2 3 4 5
C. Developing an appreciation for chemistry.	1 2 3 4 5	1 2 3 4 5
D. Developing and using observational skills.	1 2 3 4 5	1 2 3 4 5
E. Providing extensive experience with laboratory equipment.	1 2 3 4 5	1 2 3 4 5
F. Designing experiments.	1 2 3 4 5	1 2 3 4 5
G. Carrying out instructions carefully.	1 2 3 4 5	1 2 3 4 5
H. Recognizing and understanding scientific terms.	1 2 3 4 5	1 2 3 4 5
I. Generating hypotheses.	1 2 3 4 5	1 2 3 4 5
J. Understanding the value and limitations of physical laws.	1 2 3 4 5	1 2 3 4 5
K. Relating science to career opportunities.	1 2 3 4 5	1 2 3 4 5
L. Developing a systematic approach to problem solving.	1 2 3 4 5	1 2 3 4 5
M. Using scientific terminology and conventions.	1 2 3 4 5	1 2 3 4 5
N. Verifying results.	1 2 3 4 5	1 2 3 4 5

	12 Adv.	Grade 13
O. Drawing and supporting conclusions.	1 2 3 4 5	1 2 3 4 5
P. Understanding information presented in symbolic form.	1 2 3 4 5	1 2 3 4 5
Q. Reading and interpretating graphs.	1 2 3 4 5	1 2 3 4 5
R. Using graphs to present results from experiments.	1 2 3 4 5	1 2 3 4 5
S. Differentiating between fact and opinion.	1 2 3 4 5	1 2 3 4 5
T. Observing chemical similarities and differences.	1 2 3 4 5	1 2 3 4 5
U. Presenting observations in written form.	1 2 3 4 5	1 2 3 4 5
V. Recognizing patterns in observations and data.	1 2 3 4 5	1 2 3 4 5
W. Studying experiments for flaws in design.	1 2 3 4 5	1 2 3 4 5
X. Making generalizations on the basis of results or observations.	1 2 3 4 5	1 2 3 4 5
Y. Understanding of the need to be cautious when handling chemicals.	1 2 3 4 5	1 2 3 4 5
Z. Understanding Science as a highly unified and consistent view of the world rather than a collection of isolated facts.	1 2 3 4 5	1 2 3 4 5
AA. Incorporating controls in an experiment.	1 2 3 4 5	1 2 3 4 5
BB. Following proper safety precautions in a lab.	1 2 3 4 5	1 2 3 4 5
CC. Developing interest in science and science-related activities.	1 2 3 4 5	1 2 3 4 5
DD. Developing a student's interest in a science-related career.	1 2 3 4 5	1 2 3 4 5
EE. Taking careful measurements.	1 2 3 4 5	1 2 3 4 5

IX. Over the Instructional year what percentage of class time do students spend. . .

		12 Adv.	Grade 13
A	doing experiments	______	______
B	discussing experiments	______	______
C	making graphs from experimental data	______	______
D	writing up experiments (describing/reporting, experimental observations)	______	______
E	discussing scientific issues and values	______	______
F	watching teacher demonstrations	______	______
G	doing problems in class	______	______
H	watching films, videotapes	______	______
I	doing computer activities	______	______
J	other (specify) ______________________	______	______
		100%	100%

APPENDIX B

STUDENT ATTITUDE QUESTIONNAIRE

Note: Items marked with an asterisk (*) were the triple-response items. Accompanying each one were three five-point scales--

1. "Not at all important" to "Very important"
2. "Dislike a lot" to "Like a lot"
3. "Very difficult" to "Very easy"

Except for these triple-response items, all statements from 25 onwards were the attitude items. After each item, the number in brackets is the average response, where 1 = "strongly disagree"; 5 = "strongly agree"; and 3 = "undecided." The standard error of these means is about ± 0.03.

Questions 1-12 were given to all students, 13-18 to approximately half of the students and 19-96 to approximately one-fourth of them. As a result, there were over 12,000 responses to 1-12, 5-6,000 responses to 13-18, and 2-3,000 responses to 19-96.

1. In which grade are you registered?
2. Are you male or female?
3. What is your date of birth?
4. Which of the following statements best describes the language(s) spoken in your home?

   1 My family and I speak only English at home.
   2 I usually speak English, but my family speaks another language at home.
   3 My family and I speak a language other than English at home.

5. Complete the following statement: Four years ago (in May 1979), I was . . .

1 in school in Ontario

2 in school in another province

3 in school in another country

4 not in school

6. Do you have a part-time job after school?

1 Yes

2 No

Do you have a part-time job on the weekends?

1 Yes

2 No

Is this chemistry course required for your post-secondary plans?

1 Yes

2 No

3 I don't know

7. Will you continue your study of chemistry in Grade 13? (Answer only if not taking Grade 13 chemistry now.)

1 Yes

2 No

3 I don't know

8. Which of the following courses are you taking or do you plan to take in Grade 13?

1 Algebra

2 Biology

3 Calculus

4 English

5 Relations and Functions (Analysis)

6 Physics

7 Not going on to Grade 13

9. After leaving high school, I will most likely

1 Go on to university full time

2 Go to a college of applied arts and technology full time

3 Take a private business or trades course

4 Look for a full-time job

5 Work part time and study somewhere part time

6 Other

10. I intend to pursue a science-related career after leaving high school.

1 Yes

2 No

3 I don't know

11. Approximately how many hours of chemistry homework have you been doing each week outside of class?

1 None

2 Less than 1 hour per week

3 1 - 2 hours per week

4 2 - 3 hours per week

5 3 - 4 hours per week

6 4+ hours per week

12. How do you feel about the amount of homework you are assigned in chemistry?

1 Too much homework assigned

2 Right amount of homework assigned

3 Not enough homework assigned

13. What percentage of your chemistry homework time do you normally spend on each of the following?

1 Doing problem exercises

2 Writing up lab reports

3 Reading sections out of the textbook

4 Preparing for a class lab

5 Other

14. Approximately how many hours of homework do you usually do each week, including weekends, for all subjects (total)?

1 None

2 Less than 3 hours per week (about ½ hour per day)

3 3 - 7 hours per week (½ - 1 hour per day) 7 - 11 hours per week (1 - 1½ hours per day)

4 11 - 14 hours per week (1½ - 2 hours per day)

5 More than 14 hours per week

15. How do you feel about the amount of chemistry homework you do?

1 I don't do enough

2 I do enough to pass

3 I do extra because I want to get good marks

16. Please indicate how important the following kinds of homework are. Use a "1" for most important, "2" for next in importance, "3" for next, and a "4" for least important.

1 Doing problem exercises.

2 Writing up lab reports.

3 Reading sections out of the textbook.

4 Preparing for a class lab.

17. Is there a computer available for use in your chemistry course?

1 Yes

2 No

18. Have you used a computer in your study of chemistry?

1 Yes

2 No

19. How often do you use a calculator in your chemistry course?

1 Not at all

2 Once in a while

3 Every week

4 Every day

20. Do you have open book exams in chemistry?

1 Always

2 Sometimes

3 Never

21. Do you know how to make effective use of a textbook for an open book exam?

1 Yes

2 No

3

22. Do you find the textbook easy to use during an open book exam?

1 Yes

2 No

3 I don't know

23. I prefer to read why things happen rather than to do an experiment to find out. (2.3)

24. I would rather watch the teacher do experiments than do them myself. (2.1)

25. It is better to be told scientific facts than to try to discover them from experiments. (2.3)

26. Doing experiments is too slow a way to learn chemistry. (2.1)

27. Doing experiments did not help me learn chemistry. (2.1)

28. I would like to spend more time doing experiments. (3.5)

29. I find that doing experiments helps me to understand chemistry. (3.9)

30. I would rather do experiments myself than watch other students do them. (4.0)

31. I would rather work with someone else than do experiments by myself. (4.0)

32. I would rather do experiments that involve measurements than experiments involving only qualitative observations. (2.9)

33. I like to try out new ideas by doing chemistry experiments. (3.6)

34. I am interested in the unexpected results that sometime occur in chemistry experiments. (3.9)

35. I enjoy demonstrations or experiments which give unexpected results. (3.9)

36. *Setting up an experiment.

37. *Working with others on experiments.

38. *Working alone on experiments.

39. *Cleaning up after a chemistry experiment.

40. *Following the teacher's plan for an experiment.

41. *Handling scientific equipment and apparatus.

42. *Recording the observations of experiments.

43. *Writing lab reports.

44. Working in a chemistry lab would be interesting. (3.7)

45. I enjoy reading about science in books and magazines. (3.5)

46. Experimental results can be interpreted in different ways. (3.8)

47. It is important to know the expected result of an experiment before it is performed. (3.0)

48. If you know what the result should be, there's no point in doing an experiment. (2.1)

49. *Generating theories to explain observations.

50. *Designing experiments to test theories and laws.

51. *Explaining the results of an experiment.

52. *Discussing experiments done by other students.

53. *Discussing experimental results in class.

54. I like to visit science museums. (3.7)

55. I would like to belong to a science club. (2.5)

56. I like to watch T.V. programs on science. (3.5)

57. Chemistry lessons are fun. (3.1)

58. I feel good when I solve a problem myself. (4.5)

59. I really want to do well in chemistry. (4.4)

60. Chemistry experiments are fun. (3.9)

61. Everyone should learn something about chemistry. (4.0)

62. Chemistry experiments can be frustrating. (3.5)

63. My parents think it is important to take chemistry. (3.4)

64. My parents want me to do well in chemistry. (4.1)

65. *Memorizing scientific laws.

66. Chemistry is harder for me than it is for most other people. (2.5)

67. I find chemistry the easiest of the science courses. (2.6)

68. I find physics the easiest of the science courses. (2.3)

69. I find biology the easiest of the science courses. (3.2)

70. Even complex chemistry can be made understandable to high school students. (3.4)

71. The most difficult part of the chemistry course is learning to use laboratory equipment. (1.7)

72. Learning chemistry involves mostly memorizing. (2.9)

73. I get annoyed when I don't get the expected results in chemistry. (3.3)

74. *Discussing science programs seen on T.V.

75. *Relating results in the lab to the "real world" (trying to make a connection between what is done in the lab and the "real world").

76. Chemistry is dangerous. (2.4)

77. I would like to make a significant contribution in science. (3.2)

78. Most jobs in the future will require some scientific knowledge. (4.1)

79. Most jobs today require some scientific knowledge. (3.9)

80. Chemistry plays an important role in our country's development. (4.0)

81. Chemistry will play an important role in our country's development. (4.0)

82. More scientists deserve public recognition. (3.6)

83. Money spent on scientific research and development is money well spent. (4.1)

84. Money spent applying the results of scientific research is money well spent. (4.0)

85. Discoveries in chemistry have changed how people think about the world. (4.2)

86. A good knowledge of chemistry helps people understand the world better. (3.9)

87. Chemistry has improved our standard of living. (4.0)

88. Man-made chemicals do more harm than good. (2.6)

89. So far, there have been more good outcomes of chemistry than bad ones. (3.7)

90. There should be chemistry magazines written for the general public. (3.6)

91. More scientists should do demonstrations on T.V. (3.1)

92. I like to read about scientists as people. (2.8)

93. Our chemistry course does not give enough information about the lives of scientists. (2.7)

94. Many scientists are interested in music and the arts. (3.0)

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